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GEORGE W. BATCHELDER,

President New England Water Works Association,

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME NOTES ON TROPICAL WATER SUPPLY AND STUDY OF FILTRATION AT PANAMA.*

BY HERMAN K. HIGGINS.

DISCUSSION.

[*January 24, 1912.*]

Mr. E. W. Clarke † (*by letter*). This paper is of special interest to the writer as he was resident engineer on the Colon Water Works during most of the time referred to by Mr. Higgins.

The first part of Mr. Higgins's paper is evidently intended to be more interesting from a humorous standpoint than from an engineering one, but I think, in justice to those connected with the work, the impression which might have been left in the mind of any one reading this paper that the development of the supply for Cristobal and Colon was a haphazard operation should be corrected.

Colon was built by and because of the Panama Railroad, and while the writer has no personal knowledge of the early water supply at this city, as soon as the railroad shops were established, a supply was furnished to them from a small reservoir at Mt. Hope, and incidentally the inhabitants, who were mostly railroad people, were supplied with water during the dry season. During the balance of the year, — that is, from the middle of April to the end of December, — no artificial supply was necessary for drinking purposes, and such things as closets or baths did not exist outside of the houses of a very few of the higher officials. As Mr. Higgins states, water was at times brought from the Frijoles River for

* Journal N. E. W. W. A., Vol. 25, p. 454.

† Division Engineer, New York Board of Water Supply.

drinking purposes only, and supplied to the people at the water stations, one of which is shown on Plate III of Mr. Higgins's paper.

The Panama Railroad Company had at least two sources of supply during the years previous to 1900, both of which were extremely small, but were sufficient to serve their purposes, and they never pretended to supply the city of Colon with water. The water stations were maintained for the use of their own employees during the dry season, who received water free, and for non-employees on the payment of a nominal fee.

After Cristobal was built, a water supply was obtained for a time from the west side of Limon Bay, as described by Mr. Higgins, from a stream draining a very small catchment area on the east side of the hills east of the Chagres River. Later, an infiltration well was sunk near Mt. Hope Station, — or Monkey Hill, as it was then called, — three standpipes holding about 30 000 gal. erected on a nearby hill, and a 4-in. main laid to Cristobal with a small distribution system in the town. No connections were made to the houses with the exception of two buildings locally known as "De Lesseps palaces," while the general inhabitants were served with one hydrant in each street. In the De Lesseps palaces, a limited number of faucets were placed, and two shower-baths. This system was not in operation when the United States took possession of the canal in May, 1904, but the resident engineer on the canal work at Cristobal repaired the pump at the well, and got the system into partial running order sometime in June of that year.

The writer arrived on the Isthmus in the latter part of July, and reconnoissances and surveys were begun for the location of an adequate supply of water for both Colon and Cristobal. The possible sources were four in number, and three were quickly eliminated for economic reasons. The fourth was on Brazos Brook about two miles east of Mt. Hope Station, and it was largely a matter of Hobson's choice that this brook was selected as a source of supply, as it was recognized from the beginning that the reservoir would be a shallow one, and that conditions would be ideal for the growth of algæ. A report on the subject with plans and recommendations as to details of work was made to my superior

in December, 1904, and authorization to begin construction was received in March, 1905.

In December, 1904, I was instructed to take charge of the maintenance of the water supply for Cristobal, and as the infiltration well mentioned gave evidence that it would be unable to supply the demand, it was imperative that some quickly available substitute be found. About three quarters of a mile east of the railroad at Mt. Hope was the unfinished east diversion channel for the Chagres River, connecting at Mindi with the Mindi River, which in turn flowed into Limon Bay. The water in the channel during the wet season was fresh, and it was hoped that the volume was great enough so that it would remain at least suitable for boiler use during the dry season.

Two old French pumps were set up at the end of this channel, and a pipe line laid to connect with the standpipes mentioned as being part of the old French system. At this time, no cast-iron pipe had been delivered on the Isthmus, and this line was made up of old French pipe, both cast- and wrought-iron, from $2\frac{1}{2}$ in. to 4 in. in diameter. As very few specials were to be found in the storehouse, changes from one size to another were made by pushing the smaller pipe into the larger, leading up the joint as well as possible, and placing concrete around it. The result of such construction was, of course, enormous friction. The static head was about 35 lb., but the pumps habitually ran under pressure of 65 to 70 lb., and as they were not designed to work under such pressures, the leather valves were continually giving out.

In spite of this, we managed to pump about 30 000 gal. per day into the standpipes. This was largely due to the patience and efficiency of the white machinist in charge of the pumps, who lived in a shack within a stone's throw of the station, and was up at all hours of the day and night endeavoring to make up for the inefficiency of the plant with which he was working. His assistants were Jamaica negroes, who were usually extremely ignorant and careless, and twice, during the operation of these pumps, crown sheets were burned out, necessitating the replacement of the boiler.

The pumps were not the only source of trouble in operating the system. Leaks were of weekly occurrence in the pipe line, and

one valve had an annoying habit of closing from its own weight on account of the thread being stripped from the stem. The "very short, very fat, very profane" man, spoken of by Mr. Higgins, spent most of his waking time keeping this line in service.

As Mr. Higgins states, a distribution system was laid through Cristobal, and early in 1905 practically all the houses were provided with showers and water-closets, which was a decided improvement over the condition six months previous, when there were two shower-baths in town and water-closets were unknown.

By the 1st of April, the water in the diversion canal became brackish and finally practically salt water, so it was used only for flushing purposes. For drinking purposes during the early part of the dry season, dependence was placed on the rain-water barrels, which had been screened by the sanitary division, and as these barrels were generally in places easily accessible to any one, the consequence was that the negroes took water from any tank they saw fit, and by the 1st of February the supply was practically exhausted. Recourse was had to six reserved rain-water tanks having a combined capacity of 65 000 gal., and while an effort was made to restrict the use of this water to drinking exclusively, and daily permits were issued for this purpose, doubtless a considerable portion was used for washing. This tank supply finally failed, and water was then hauled from Frijoles by the railroad for a period of two or three weeks, and pumped into tanks, as shown by Plate I of Mr. Higgins's paper, which is a view probably taken in April, 1906, in the easterly part of Cristobal.

In May or June, pipe began to arrive from the United States for use in the Panama system, and sufficient 6-in. pipe was diverted to relay the line from the diversion canal to the tanks, and also to repair the 4-in. line. The pressure on the pumps promptly dropped to about 40 lb., and our pump troubles were over. Previous to this, a small dam had been built near the pumps, which collected water from a small drainage area, and the heavy rains of the latter part of May filled the pond, and gave fresh water for use at Cristobal.

It was realized that it would be impossible to construct the main dam, outlined in the report on the Colon Water Works, in time for use during the dry season of 1905–6, and, therefore, the temporary

dam at the upper end of the watershed was constructed during the summer of 1905. Here again, we were working under most adverse circumstances, due principally to lack of material. For instance, in order to control the water during the placement of the embankment, a 4-ft. flume was designed to pass through the dam, and as it was impossible to get any dimension lumber on the Isthmus at that time, it was built up of four layers of 1-in. tongued and grooved California redwood, nailed together on forms, giving practically a circular section, and reinforced with telegraph wire, clinched up by means of home-made contrivances around the outside. This makeshift naturally enough gave trouble, and before the dam was entirely finished, we were forced to place posts nearly its entire length to prevent its crushing.

The site of the temporary dam was nearly a mile from the end of the narrow gage railroad to the main dam, and neither time nor number of men permitted the construction of a roadbed capable of supporting even our three-ton locomotives, so a line on which cars were pushed by hand was laid, and over this was hauled such material as we were absolutely forced to import for the construction of the dam. The cost of transporting coal prevented the use of steam for pumping, and an old hand fire engine, which we found at Cristobal, was put into service at the dam, and pumped water to puddle the bank. This dam was finished in time to collect the rainfall during October and November, 1905, but the abutting hills and the foundations proved so very pervious that a very considerable leakage occurred, and a secondary dam was built a few hundred feet down stream. The 8-in. spiral riveted pipe line passed through this latter dam, and towards the end of the 1905–6 dry season, the leakage from the upper dam was admitted into the pipe at this point, so that while, as Mr. Higgins states, the water in the upper reservoir was below the outlet of the pipe, a large proportion of it was eventually caught and used at the lower dam. In the meantime, the 20-in. pipe line from the main reservoir for Colon had been laid as far as the diversion channel, a connection made with the pump at this point, and Cristobal was supplied from Brazos Brook-shed during January and February, 1906. When this supply finally gave out, recourse was had to the diversion canal, salt water was again pumped into the

mains, and tank cars brought fresh water down from Frijoles. The writer left the Isthmus in May of 1906, and has no personal knowledge of later conditions.

The only claim which the work done by the Municipal Division on the Isthmus during 1904–6 has for recognition by the profession is in the difficulties under which it was accomplished.

Fortunately, the *morale* of the engineering force was most excellent, and every one of the men did the best he could to make the work a success, and it was owing to this attitude on the part of the members of the force that in spite of difficulties due to lack of material and of labor that the first two years of the American occupation of the Isthmus saw the completion of the design and construction of water works and sewer systems for practically every town on the Isthmus and also for the cities of Colon and Panama. The men put up with discomforts and inconveniences of which later arrivals on the Isthmus had very little idea, and while the experience can be laughed at as we look back upon it, it was anything but laughable at the time; and the work done, while doubtless having many defects, was the result of a great deal of hard work and ingenuity on the part of every member of the Municipal Division. What has been said of the work at Colon and Cristobal applies with equal force to the work done at all the towns across the Isthmus.

THE RELATIVE CORROSION OF IRON AND STEEL PIPE AS FOUND IN SERVICE. [ABSTRACT.]

BY WILLIAM H. WALKER, PH.D., PROFESSOR OF INDUSTRIAL CHEMISTRY AND DIRECTOR OF THE RESEARCH LABORATORY OF APPLIED CHEMISTRY, MASS. INSTITUTE OF TECHNOLOGY.

[*Read December 13, 1911.*]

There are few subjects relating to the corrosion of metals which have received so much attention, or around which there has centered so spirited a discussion, as the relative merits of iron (meaning thereby wrought iron) and steel. The fact that this matter is one still receiving attention, notwithstanding the great volume of accumulated and available literature, is due to a number of causes, among which may be mentioned; — first, that although the words "iron" and "steel" carry with them a definite idea as to general methods of manufacture and some of the more easily discernible properties, they convey no idea as to standards of value. It is possible to make very poor iron and very good steel, and it is just as possible to make the reverse. Hence, when an investigator compared the corrosion of a poor iron with a good steel, he obtained results which favored steel; when the material under study was the reverse, iron was shown to be the more resistant metal. Second, there is a woeful lack of uniformity of conditions obtaining in many if not most of the experiments which have been carried on for the purpose of comparing resistance to corrosion. Some specimens were large, some small; some cleaned of scale, others not; some immersed in deep water, others in shallow water, etc. The corrosion of iron is so sensitive to changing conditions of surface, oxygen concentration, salts in solution, and the like, that only when the most careful preparation is made to maintain all conditions constant, is a comparative test of value. We will not discuss these conditions here, but take pleasure in referring the reader to that most excellent book, "The Corrosion of Iron and Steel," by Dr. J. Newton Friend, where a complete treatment of the general subject will be found. Third, many times opinions are formed and

expressed by the casual observer which fail to take into consideration not only the fundamental conditions necessary to accurate comparative work, but also less obvious conditions which make a comparison unreliable. For example, a person may notice the rapid rusting of a cheap grade of steel wire fencing which had originally but a wash of zinc as a substitute for galvanizing, and thus become suspicious of the durability of all steel. Or he may notice holes in a metal roof put up in place of a material known to have lasted a much longer time than the new roof. He concludes that the later is of less value without having any knowledge of the change of conditions in the locality, class of metal, and the thickness of the new roof, nature and thickness of the galvanizing or other protective coating, and so forth.

Owing to the proverbial conservatism of New England, the introduction of steel pipe has been slower in this territory than in other parts of the country. There is a tendency to pronounce any pipe which withstands corrosion as being wrought iron, while the fact that a pipe corrodes easily is considered by many proof in itself that it is steel.

To determine what the facts actually are in regard to the relative life of service pipes which have been in constant use for a considerable number of years throughout New England, an investigation was undertaken in which it was proposed to seek out instances where steel and iron pipe had been used together in the same system; and further, where the two kinds of metal were separated in this system only by a coupling. Any influence which the coupling might have would be present equally with the iron and with the steel, while conditions of oxygen concentration, temperature, pressure, flow of water or steam, etc., would be as nearly identical for the two kinds of metal as it is possible to obtain. It was intended also to collect in this way material of known resistance or tendency to corrosion, in order to further test the applicability or truthfulness of the so-called "acid corrosion test." While the majority of the pipe so obtained was from hot and cold water feed systems, enough were selected from live and exhaust steam lines, hot-water and steam-heating systems, etc., to make the conclusions drawn of general application. The investigation was necessarily tedious in that each pipe had to be examined to determine whether

it was of iron or steel, and many instances were found that would have served our purpose well, but where it was impossible to remove the pipes from the system. The pipes were sent to the laboratory where they were each split lengthwise into halves, and carefully cleaned from scale and rust by soaking in an ammonium citrate solution, with an occasional brushing. In this way the scale and rust were removed without dissolving any of the iron. An estimation of the extent of corrosion was made by measuring with a micrometer gage the ten deepest pits per unit distance of length.

The results are a splendid vindication of the principle that if oxygen be excluded or taken from water, no corrosion will take place. When the water in the lines examined was stagnant, as in fire-sprinkler systems for buildings, or in lines where the water was circulated over and over again without exposure to the air, as in some hot-water heating systems, no corrosion was to be observed. On the other hand, where fresh water was constantly added to the system, and heated within the system, corrosion was very rapid and in some cases excessive.

We were able to get sixty-four comparisons of iron and steel where the history of the installation was known. The results are as follows:

Comparisons where iron was found more corroded than steel,	20
Comparisons where steel was found more corroded than iron,	18
Comparisons where steel and iron were equally corroded,	9
Comparisons where corrosion was negligible,	17

These results again demonstrate that taken *on the average* there is no difference in the corrosion of iron and steel pipe. Conversations held with the engineers in charge of plants during this investigation confirm the statement already made that a pipe is frequently called steel when corrosion is found to be excessive, while it is set down as iron if it rusts but little.

In order to get some measurement of the influence of oxygen in the water of the modern hot-water supply system, a relatively large scale experiment was carried on at the plant of the Walworth Manufacturing Company in South Boston. Two coils made up from pieces taken from the same length of pipe were each fed with

water from the same source at the same temperature. In one case the water was heated to 85 degrees cent. in an *open tank*, while in the other the water was heated to the same temperature in a *closed* tank. The feed water contained on the average 5.85 cc. of oxygen per liter, and passed through each coil at the rate of one-half gallon per minute. After running 1 750 hours the coil fed with water heated in an open tank had lost 22 gm., while the coil fed with water heated in a closed tank had lost 155 gm. In neither case was the oxygen completely removed; if the water in the open tank had been gently *boiled*, corrosion in the coil fed with this water would have been entirely prevented.

In order to show what relation may exist between the so-called acid corrosion test and the real corrosion as found in service, eleven pairs of iron and steel were selected and subjected to 20 per cent. sulphuric acid for four hours at room temperature. Four pairs were selected in which the steel was decidedly better than the iron in service, four in which the iron had shown decidedly better than the steel, and three in which there was no difference between the two metals.

In six instances the relative corrosion as shown by the sulphuric-acid test corresponded with the corrosion as found in service. In five instances corrosion as shown by the acid test was exactly contrary to that found in service. Although the greatest care was taken to have the specimens of the same size, cleaned in the same way, and in the same physical condition, the results show that no reliance can be placed in this accelerated acid test, but that it may be entirely erroneous and very misleading. Not only did the acid test not agree with the service test when steel was compared with iron, but the steels failed to agree among themselves, and the irons showed no agreement when considered by themselves.

DISCUSSION.

THE PRESIDENT. It was known long ago that pipes rusted, corroded, and in time had to be replaced. But when pipes are corroded there is action and reaction; the pipe is destroyed and the water also is affected. Some of the iron goes into solution in the water, and afterward, when the water is drawn, the iron

separates and makes the red-water trouble we have heard so much about.

Now, my friends the pipe men tell me that if we will only give them a decent water to put through the pipes, the pipes will be all right, and some of the superintendents say that, if we only had decent pipes to send the water through, the water would be all right. There is probably some truth on both sides, and we want to find out to-day as much about it as we can, and see what kind of treatment will clean up this red-water trouble. We have heard from Professor Walker of the Institute of Technology, who has been studying this subject most carefully for several years, and have discovered a new point of view as to the quality of water. We are to consider it from the standpoint of the pipe. We have learned that a good water, from the standpoint of the pipe, is one that does not carry oxygen, that does carry plenty of organic matter, and that is also hard.

Now, gentlemen, that is not the standard we have been working for from the standpoint of the consumer. Perhaps we have been looking at it from a wrong point of view. We have been trying to give the people water which was good for them, but perhaps we shall have to turn about and give the pipe water that is good for the pipe.

Mr. Speller represents a company which, a few years ago, was a very large, perhaps the largest, manufacturer of wrought-iron pipe in the country, and his company has now given up making wrought-iron pipe and is making only steel pipe. I am going to call upon him to say what he can for himself, and justify his course if he can. And in doing this, I want him to bear in mind that this is not altogether a question between steel pipe and wrought-iron pipe; it is not a question whether he can get the wrought-iron business for the steel pipe, but it is a question whether either steel pipe or wrought-iron pipe is going to answer the requirements of the members of this Association for the water which they supply to their consumers.

Mr. F. N. Speller.* *Mr. President and Gentlemen,* — From what has just been said I judge you are aware that we have followed this question as between wrought iron and steel pretty

* Metallurgical Engineer, Pittsburg, Pa.

closely, and that we have been particularly interested, especially during the past six or eight years, in the matter of durability. Naturally so, because most of our product cannot usually be protected by coatings, and therefore it becomes very important to make it as durable as possible in the natural state. Our work has been very largely furthered by the researches of such scientific investigators as Professor Walker. They have laid the foundation on which we, who have less time to go deep into fundamental principles, have worked.

Dr. Walker's work has been so extensive in New England as to be practically conclusive as regards pipe in that district; but it may be just as well to give the results of similar investigations in other localities which Dr. Walker's researches closely corroborate in order to broaden out the scope of our conclusions.

We have records of four similar investigations (Table 1, page 17) made on pipe in water lines where wrought iron and steel were used together; I do not know why they were put in together, but there they were so found. More than likely it was simply accidental.

In the first place, you will find in the *Engineering News* of December, 1910, a report on the condition of the hot-water lines in the New York City bath houses, made by Prof. Ira Woolson for the city of New York. Eighty-nine samples were secured, seventeen of which were wrought iron. The corrosion was reported as practically equal.

The next one we come to is an investigation made in the boiler feed-water lines of the Frick Coke Company, at Scotdale, Pa. Here we have an entirely different class of water in a different locality. The relative corrosion there was found to be 100 in the case of wrought iron as against 99 in the case of steel. The average depth of the pitting in 21 lots, including the wrought iron and steel samples, was .112 of an inch in the wrought iron and .108 in the steel. In all these investigations there was found for the same length of exposure a very considerable difference between one sample and another, as much as 25 per cent. one way or the other, but on averaging up a sufficient number of samples in the same system, or in different systems, and making comparison, the results come out almost exactly the same, as Dr. Walker has found in New England.

Another investigation was made in the Cresson coal fields, with water of various characters, and leads to the same conclusion, viz., — 100 for the wrought iron as against 99 for the steel.

Later still, in the past summer, it happened that the hot-water supply lines gave out in the Allegheny General Hospital. This pipe was put in seven or eight years ago and it was decided to remove the entire system. This offered a splendid opportunity, and by arrangement with the architects we put one of our research men on the plant with instructions to take a sample from each length of pipe as it was taken out, leaving a portion of each length with the architects for independent examination. Out of 69 samples taken from the hot-water system, 42 were wrought iron and 27 turned out to be steel. The average depth of pitting in the wrought iron was .092 of an inch and in the steel .094, — practically the same again.

So we have, including Dr. Walker's research, over 150 cases where a true comparison between iron and steel pipe is possible.

So many factors are introduced in corrosion where the metals are exposed to the atmosphere or underground that it becomes very difficult to make a comparison, and no comparison can be safely made unless both materials are put into service at the same time and in such a way as to leave no doubt as to the environment being practically the same. The conditions which obtain inside a water line as in the cases cited we can agree, I think, meet the requirements of a perfect comparison as near as can be, for here we have the two materials coupled together and carrying the same water both as to quality, quantity, and temperature.

We have made galvanic tests of wrought iron and steel to learn if there was any difference of potential and find a slight difference, but not always in the same direction, for sometimes the wrought iron and at other times the steel will be the anode. Moreover, the current tends to reverse itself as corrosion proceeds, the anode because of the hydrated oxide which collects on its surface becoming the cathode. In any case the current caused by contact is so exceedingly weak as not to influence the corrosion of the metal more than a small fraction of an inch away from the contact, and

all comparisons as to pitting in the tests referred to were taken at a safe distance from the joint.

The results of these experiments also indicate the error of the claim that absence of manganese * and the presence of considerable cinder † are controlling factors in lessening corrosion. Mill scale which forms on the surface of iron and steel on cooling in the air has the strongest potential difference of all the materials which are likely to be found in or in contact with iron and is the most frequent cause of pitting. Mill cinder which is formed in irregular patches and strings in puddled iron has about the same difference of potential, and, being decidedly electro-negative to iron, greatly accelerates the solution of the metal. There may be something in the claim of the mechanical protection from cinder, for it is a good protector when the entire surface of the metal is covered, but this protection becomes worse than useless when the cinder is in exposed contact with the iron, as it then causes corrosion to proceed at irregular and greatly accelerated rates on the exposed surface, which results in the familiar phenomena known as pitting.

Another instance where a true comparison may be drawn might be here referred to (and many more could be added), since it indicates that the general conclusion we are forced to regarding pipe materials is not restricted to water lines. About thirteen years ago in the Ohio and Indiana oil field some operators started to use steel casing for the wells and it later came to be used exclusively by these companies, but for a few years wrought iron and steel were kept in stock and put in together, as it frequently happened, in the same well. By examining a number of strings of casing recently pulled which date back to this period, cases were found where the iron and steel were screwed together, and invariably where one is affected the other is damaged to practically the same degree. The same may be said of the couplings which have always been made of iron, an example of which is shown in Plate I. So far, then, as the steel pipe made during the past twelve years or so is concerned, there appears to be little to choose between it and the wrought iron of the same period. It might be inferred from

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* An investigation described in *Journal of Iron and Steel Institute*, Vol. LXXXIII, p. 189, 1911, indicates that manganese compounds tend to protect iron from corrosion.

† See p. 172 (*Ibid.*) as to the influence of cinder and mill scale.

Comparison of Steel Pipe and Iron Couplings from Indiana Oil Fields, after 15 Years' Service.

this experience that since some of the factors controlling corrosion have been better understood and steel has been made with due regard to its durability in the light of the late scientific study of corrosion, that modern steel so made is superior to wrought iron, and tests under way indicate this to be the case, although non-corrodible iron has yet to be discovered.

How, then, some of you will ask, can we explain certain experiences which have been cherished almost as trade marks by some of our friends who still claim to be manufacturing wrought-iron pipe? It has been found in a few isolated cases that wrought-iron pipe made before steel pipe was thought of has outlasted steel put to the same use many years after. It is hardly likely that the wrought iron made in the early days of pipe manufacture was so much better or the steel so much worse than nowadays, although this may in some measure account for such cases. It seems more probable that the early history of the treatment of the surface of these old pipe in or after manufacture, whereby it acquired some effective protection, will account for such cases of extraordinary resistance to corrosion. The strong resisting qualities of a silicious iron scale formed in manufacture or the natural scale formed and dried on the surface by years of exposure under mild conditions of intermittent corrosion may afford the necessary permanent protection, if indeed it was not after all due to a forgotten coat of good paint, for the early history of these isolated cases cannot be said to be known with any degree of certainty. In a study of the corrosion of metal on the Panama Canal two years ago, we found several cases of this kind in looking over some old French junk — of course, as in other instances, these pieces of apparently unprotected pipe were conspicuous by their rarity, most of this material not so fortunate having dissolved and disappeared. Some of these pipes which showed no evidence of paint, but which had a thin, hard, badly weathered scale, were threaded for a foot or two and hung up to the moist breeze on the Pacific coast with some pieces of new steel pipe of about the same thickness, which, of course, were similarly treated. In six months they were both badly and equally corroded and the old iron was found to have lost more in this time than in the previous twenty-five years.

The apparent inconsistency between the facts as found in these

investigations and the opinions quite generally held as to the superiority of wrought iron is not difficult to understand when we consider —

1. How few who hold to this opinion base it on anything more than what they have heard others talk of, whose experience frequently amounts to nothing but general observation or inference from results of what they have seen with iron or steel products other than pipe, from which it is unfair and misleading to draw comparison.

Confusion of opinion has resulted from treating the question of corrosion too generally. We cannot compare all kinds of steel as a class with all sorts of wrought iron. We are just beginning to learn that well-made sound steel is not only as durable as the best wrought iron on record, but for special conditions, for example, where acid conditions prevail, steel may be made so as to be many times more resistant than iron.

2. From the demonstrated fact that the majority of those handling pipe day by day are half the time unable to tell wrought iron from steel.

3. That corrosion conditions are generally much more severe nowadays and have become more so, much in the same ratio as the relative proportion of steel pipe has increased, so that it would only be natural to connect the more general use of steel with the observed decrease in useful service of pipe in certain localities.

4. The important influence of the man who handles the pipe, who not infrequently prefers wrought iron as being somewhat easier to thread with the average die and because it is a union-made product as against steel made in non-union mills.

All these and other influences which have been used to fan and keep alive a prejudice, steel pipe has had to contend with and live down.

The President. Gentlemen, there seems to be no doubt but what many samples of wrought-iron pipe in the old days lasted much better than the pipe which has been put in recently, and Mr. Speller, I see, goes back to the idea that perhaps the water that they had in the old days was better for the pipe than the water that we have now. I expect that was often the case, because it seems to be generally true that the cleaner the water, the harder

TABLE 1.

CASES OF COMPARISON OF WROUGHT IRON AND STEEL UNDER INTERNAL CORROSION IN WARM WATER SUPPLY LINES.

Summary of Results of Investigations on Record during the Past Two Years.

Locality.	Number of Cases on Record.	Average of Deepest Pits. W. I.	Average of Deepest Pits. Steel.	Reference for Details. Remarks.
New York City Bathhouses.	89 samples secured, of which 17 were wrought iron.	Equal 100	100%	*Engineering News*, Dec. 3, 1910, p. 630; or N.T.C. Bulletin No.2. Conditions were those of actual service and pipe was tested to destruction.
Frick Coke Co. Power Plants	21 lots, comprising 52 samples, of which 26 were wrought iron and 26 steel.	.112 in. 100% 100%	.108 in. 96% * 99% †	*Engineering Review*, April, 1911; or N.T.C. Bulletin No. 3; or Amer. Soc. Heating & Ventilating Engrs., 1911. Conditions were those of actual service, varying from 6 months to $7\frac{1}{2}$–8 years.
Cresson Coal Fields	20 samples, of which 10 were iron and 10 wrought steel.	.094 in. 100%	.093 in. 99% ‡	Preliminary report of J. J. Wilson, Aug. 29, 1911. Conditions those of actual service, varying from 6 months to 10 years.
Allegheny General Hospital	81 samples, of which 69 are from the hot-water lines, 42 wrought iron and 27 steel.	.105 in. 100% .092 in.	.105 in. 100% * .094 in. †	Preliminary report of D. R. Mason, Dec. 8, 1911. Conditions those of actual service; pipe was tested to destruction.

* Depth of deepest pit in wrought-iron samples taken as 100 per cent.

† Average depth of five deepest pits in wrought-iron samples taken as 100 per cent.

‡ Average depth of four deepest pits in wrought-iron samples taken as 100 per cent

it is for the pipe. That is a feature of the situation which must be taken into account. At the same time we find that in many important enterprises, where people are studying the conditions very carefully, they think they had rather have wrought-iron pipe, and they are willing to pay a substantial increase in price in order to get it. We want to know whether this is prejudice or whether there is some foundation for the preference. We are fortunate in having with us to-day Mr. George Schuhmann, the vice-president and general manager of the Reading Iron Company, one of the largest, perhaps the largest, manufacturers of wrought-iron pipe in the United States. I have great pleasure in introducing Mr. Schuhmann.

George Schuhmann, Esq. *Mr. President and Gentlemen,* — In order to make my arguments clear to you, I may have to bore you a little at first with a description of the manufacture of wrought iron.

Mr. Speller mentioned that iron made many years ago was probably made better than iron is made nowadays. In reply to this I wish to state that we make our wrought iron to-day in exactly the same way as it was made in the olden times after puddling was invented; that is, we puddle our iron from pig iron. As no doubt many of you know, pig iron is a cast iron, containing about 93 per cent. of pure iron. The rest is carbon, silicon, phosphorus, sulphur, etc. This pig iron is remelted in the puddling furnace (the fire chamber being separated from the melting chamber), the temperature in which is above the melting point of pig iron but below the melting point of wrought iron, and when the metal is in a molten state it is stirred up by the puddler and his helper, which causes the carbon in the iron to burn out, and as the particles of iron become purified, they partly congeal, *come to nature,* because the temperature of the furnace is not high enough to keep the pure iron liquid. The other impurities will separate from the iron, forming puddle cinder, in which the pure iron crystals float around, like sugar crystals in molasses in a vacuum pan. As more and more of these crystals congeal and come in contact with each other, they stick together, forming a spongy mass, the cavities of which are filled with liquid cinder, or, to make a homely comparison, it is like a popcorn ball, held together with molasses.

After removal from the furnace, this spongy mass is squeezed or hammered into blocks and then rolled out into bars. The cinder-coated globules of iron become elongated, giving wrought iron a fibrous structure, that is, the iron and the cinder coating get stretched out together, so that the latter is distributed through the whole body of the iron. This enclosed cinder plays a most important part in the resistance against corrosion. It consists of a silicate of iron, — an iron oxide with some silica; and because silicate of iron resists ordinary corrosive action better than pure iron, its presence in wrought iron is responsible for the fact that wrought iron resists corrosion better than steel, because the latter is a more homogeneous metal, without any enclosed cinder fibers.

Mr. Speller mentioned something about old wrought-iron pipe in use on the Panama Canal, which presumably had been furnished by the French many years ago, and which was still in good state of preservation, and he further stated that the pipe had probably been painted. Now, if a layer of paint can prolong the life of iron and steel, a fine layer or fibers of silicate of iron all through the body of the iron is also a resistance against corrosion, but, like most paint, it is only a resistance against mild corrosive influences, for if we pour acid on the paint we destroy its usefulness, and so it is with the protection afforded by the cinder in wrought iron. To illustrate this roughly, you can take several layers of blotting paper held tightly together with rubber bands. At one end between each layer of blotting paper place a layer of thin writing paper, to represent the cinder, while at the other end there is only the blotting paper, to represent the steel; or, to use the analogy of the popcorn ball, the blotting paper represents the corn and the writing paper the molasses. Now, if we pour an equal quantity of ink on the end representing the steel, the ink will penetrate several layers of the blotting paper, while at the other end the first layer of writing paper has practically arrested the penetration of the ink. If we take acid instead of ink, it is a different story, as the acid will go right through the writing paper as well as the blotting paper.

I am very much pleased to hear Professor Walker confirm our contention that acid tests are entirely unreliable as a guide to resistance against ordinary corrosion. It gives me great satisfaction to say this, because, when I made the same statement some years

ago at a meeting of the American Society for Testing Materials, some scientific gentlemen present disputed it. I believe, however, that those who have followed the discussion of this subject are now agreed that the accelerated corrosion tests are entirely unreliable and misleading.

While the protective action of the cinder fibers has been admitted, some scientific gentlemen have argued that there was not a sufficient amount of cinder in wrought iron. They had some microphotographs of wrought iron magnified seventeen diameters which showed only a few patches of cinder here and there; so they claimed this was like a picket fence that would let the wind (corrosion) blow through. Photographs magnified fifty, one hundred, and two hundred diameters, however, show that the picket fence has the pickets pretty close together.

Unfortunately, there have been some irons put on the market that are made by using old junk-yard scrap, heated up to a welding heat, *busheling or fagoting,* and then rolled out into bars, sheets, etc. When the old scrap consisted of nothing but wrought iron, it was not so bad, because wrought iron is permeated with the cinder fibers which were produced in the puddling operation, but junk-yard scrap nowadays is mixed with more or less steel, some of it, may be, high carbon or other alloy steel of various grades, and since steel is not permeated with cinder fibers, when these pieces get rolled into the iron, you have a starting point for corrosion or pitting. We fear that some of this kind of iron has been paraded as genuine wrought iron, and in some cases picked out when making comparisons with modern steel. Just as paint is a protection against corrosion on the outside of the metal, so the cinder fibers permeating wrought iron are a protection in the interior of the metal. In other words, a wrought-iron bar is like a wire rope of which every individual wire was painted before the rope was put together. The wires are the iron fibers and the paint is represented by the cinder fibers. Inasmuch as the method of making wrought iron by the puddling process is still the same as in vogue fifty or seventy-five years ago when puddling was first invented, and all the wrought iron used in our pipe is made that way, I do not see why it should not be just as resistant against corrosion as the iron which was made many years ago.

The President. I am sure we have been very glad to hear how wrought-iron pipe is made, described in a way so graphic that we can all understand; and I am sure we are glad to know that it is made in the same way that it used to be made in the good old days. Mention has been made of the fact that users often do not know whether they are using wrought-iron pipe or steel pipe. Some of our members feel that there ought to be a way of marking pipe so that the mark could not be changed, and so that every user who knew the marks could see and know certainly what mill the pipe came from. I think it would be interesting if Mr. Schuhmann and Mr. Speller would tell us before they go whether they are willing to mark their pipe so that everybody will know when they get it, and if not, why not?

We have been hearing recently about a new kind of iron, not quite a steel, although made something like steel. Is there any one present to speak for this new product which has recently come upon the market?

Mr. H. S. Kahurl. Mr. President, we expected to have here to-day a representative of the Harrisburg Rolling Mills Company of Harrisburg, who is interested in this pipe; but unfortunately he was detained in New York. I cannot personally say anything in regard to the qualities of this pipe, except that it is a new product that we have taken over and are going to sell in New England. Whether the sulphuric acid test which is spoken of is any good or not, I cannot say definitely. All I can say is that the American Rolling Mills Company of Middletown are putting out extensive advertising with the sulphuric acid test shown up on a little blue print. I can also say that a number of leading engineers of the country have endorsed that test. I see that the manufacturers of steel and of iron fall back on the argument of the long time that wrought iron and steel have been in use. As ours is a new product, we cannot, of course, bring forward any samples that have been in the ground as long as theirs.

The President. Certainly it is nothing against a new product that it cannot show long experience. The subject is now open for general discussion and also for questions, because we have Mr. Schuhmann and Mr. Speller here especially so that you gentlemen may ask them all the questions you like.

Mr. A. W. Cuddeback.* We do not use galvanized pipe any more; we have found it not satisfactory.

George Smith, Esq.† Mr. President, I am not a member of the Association, but I believe that Springfield was instrumental in getting this report from Professor Walker to-day. We had some serious trouble in Springfield with regard to water after our new supply was turned on to the city; and after the newspapers had complained of the plumbers and builders using poor material, we forwarded the report which referred to the use of steel pipe to the National Tube Company. Of course, we did not know whether it was using steel or wrought iron. We bought wrought iron sometimes and sometimes steel, but in each case we had the same trouble.

We also have the same trouble, I might say, wherever we use brass pipe. The red-water proposition is just the same. We have never been able to give the public of Springfield a satisfactory answer. A man comes into our place and asks us why he gets red water in his system, and we tell him so-and-so, but he does not believe us, simply because of the report, made, I believe, by Mr. Whipple, of the firm of Whipple & Hazen.

We would like to go back to Springfield with an answer from such a man as Professor Walker or Mr. Hazen or Mr. Speller, why we get red water in systems where we have brass pipe and copper boilers, just the same as we get it where we have iron and steel pipe and steel boilers. We asked the water department for help and they were very courteous in doing anything we asked them to do. They flushed the mains, getting out a great amount of substance which we had analyzed, and we also had analyzed the material which came from the service pipe and the boiler, and in each case it showed about ninety per cent. iron, according to Dr. Emerson, of Springfield, and about one half of one per cent. more from the service inside the building than outside.

The Springfield Master Plumbers Association is interested to have something to tell these people, when they come into their places of business, as to what causes the red water, and why we get it in systems where we have copper and brass pipe just the

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* Engineer Passaic Water Company, Paterson, N. J.

† Of George Smith & Co., Springfield, Mass.

same as where we have iron pipe. Now, any information we can get on that point from Mr. Walker would be very welcome by us.

PROFESSOR WALKER. Mr. Smith very kindly handed me a list of questions just before the meeting, and I will now do what I can to answer them.

The first question is: "How do you account for the great amount of red hard substance taken out of the street main?" If the red hard substance is by analysis 90 per cent. iron oxide it means that it is ordinary rust. The other parts are doubtless material from the water itself. We will leave this question and come back to it later, because it really takes in all the remaining questions.

"How do you account for this substance taken from the street main containing about the same amount of iron rust as the substance which is taken from the service pipe and storage tank inside the building?" I think the only answer to this is that the material is from the same source; the fact that one is found in one place and the other found in another place simply means that there is one common source, and the material is carried therefrom to both places. I do not believe there can be any answer to this other than the one that the material comes largely from the street main, and is carried mechanically by the water into the service pipes.

"How do you account for the red-water trouble in buildings where the houses are piped with either brass or lead pipe and the storage tanks are copper?" Of course, it goes without saying that you can't get iron rust, which this red material is, from a copper tank or lead pipe or brass pipe. That requires no discussion. So the answer to this question also is that the red water must come from the iron mains. In other words, the rust is formed in the mains and is carried through the mains into the house systems.

"How do you account for the sudden change in condition since we have been using Little River water?" I am ignorant of the properties of the Little River water, and I really cannot talk about it with authority because I haven't the data. I would say without much hesitation, however, that some of the factors that we have discussed here this afternoon have been intensified in the Little River water. I believe that this matter can be solved. I do not

think that the city of Springfield should lie down and suffer from red water until they know what the cause of it is; but I am not prepared to say now what the cause may be, because I have never made a study of the conditions.

"Can you tell us why it is that steel and wrought-iron pipe can be used in the city of Holyoke, which is only eight miles from Springfield, while this same pipe cannot be used in Springfield?"

The answer to that is, of course, that the conditions which obtain in Springfield do not obtain in Holyoke, therefore it must be possible to determine these conditions. I cannot now say what they are, but it must be possible to find out.

Now, coming back to the first question, "How do you account for the great amount of red hard substance taken out of the street main?" You account for it by some intensified condition of corrosion in the water. Assuming it to be true that Holyoke uses steel and iron pipe and the same water that Springfield does, and Holyoke is free from this trouble, while it is so intensified in Springfield, the trouble must be due to some difference in the local treatment or conditions. Just what these differences are can be determined only by an investigation.

Let me say, in reply to Mr. Hazen's remark, that apparently the only remedies which one can apply to water to save the pipe are those which kill the water; that it is a good deal like the old man who thought he could teach his horse to eat sawdust; the moment the horse got so he could eat sawdust, he died. You cannot put in lime, I realize that, however efficient that would be; and you cannot have too much organic matter, because you want pure water; but you can, if necessary, take the oxygen out.

I don't know whether you have followed the very important work that is being done in Australia, where there is a very expensive steel or iron aqueduct which is corroding badly. The reason why it corrodes badly is because they have such a very pure water. Mr. Hazen is right in saying that the purest water is the worst water on pipes. You will find in a boiler plant which being supplied with a spring water that is absolutely pure that the pitting and corrosion is enormous. We had a case of this kind from Cape Breton; the water used for the boiler plant was exceptionally pure and the boilers were pitting very badly. The trouble

was that there was nothing in the water to coat the pipes over. that is, to make any boiler scale. The water was saturated with oxygen, and, therefore, corrosion was rapid. The difficulty was overcome entirely by putting in open pre-heaters where the oxygen was boiled out of the water before it went into the boilers. The trouble absolutely and entirely disappeared, as it must have, because without the oxygen you cannot get corrosion.

They are doing the same thing in Australia, namely, putting in an elaborate system to take the oxygen out of the water. I do not know that we can do that, except in apartment houses. I do believe it is possible there, and it may be the solution to which we will have to come. It will not spoil the water for drinking purposes. Taking the oxygen out is not in any way, so far as I know, and I think I am right in this, depleting the water of any of its valuable constituents.

Mr. Dexter Brackett.* The service pipes used in the cities and towns comprising the Metropolitan Water District are generally of lead, but wrought-iron pipes, both plain and galvanized and lined with cement and lead, have been and are still used. Lead service pipes have been almost universally used in Boston since the introduction of water from Lake Cochituate in 1848. Investigations made at that time showed that the action of Cochituate water on lead in a few days forms a coating which for all practical purposes is impervious to water, and that the water can be served from lead pipes connected with iron mains without detriment to health.

Regarding the life of wrought-iron pipes, it is well known that pipes made of thin sheets of wrought iron, lined and covered with cement, were extensively used in distribution systems in this vicinity from forty to fifty years ago, and also that in most cases these pipes failed after from fifteen to twenty-five years' use and have been replaced by pipes of cast iron. There are, however, instances where the work was well done, and the pipe was not tapped for house services, in which the life of this pipe was much prolonged.

There is in use on the Metropolitan Works a 30-in. wrought-iron cement-lined main about two miles in length which has been in

* Chief Engineer, Metropolitan Water Works, Boston.

constant service for forty years and is still apparently in good condition.

The speaker has in his office a section of pipe 5 in. in interior diameter, bored through a wooden log, which was laid by the Jamaica Pond Aqueduct Company about one hundred and ten years ago and was used for at least fifty years for conveying water to the city of Boston from Jamaica Pond. The large end of this log or pipe is encircled by a wrought-iron ring 10 in. in diameter, $1\frac{1}{2}$ in. wide, $\frac{1}{4}$ in. thick on one side and brought to a sharp edge on the other. This ring, which was buried in the ground and exposed to moisture for one hundred years, is, so far as can be judged, in substantially as good condition as on the day it was made. It appears very doubtful whether it would be in its present condition if made of steel.

An example of the preservation of wrought iron, which the speaker attributes to the cutting off of the supply of oxygen, is the perfect condition of wrought-iron bolts in a submerged pipe line after having been buried for fifty years under the mud bottom of Boston Harbor.

THE PRESIDENT. There is sometimes trouble in the use of lead pipe, I understand, in services. Will Mr. Thomas tell us what the conditions are in Lowell as regards his service pipes?

MR. ROBERT J. THOMAS. Mr. President, our trouble with lead pipes at Lowell has not been due to the lead, but to the clogging up of the pipe due to the water containing a large amount of crenothrix, unless you are referring to the time some years ago when we were warned that the water acting upon the pipe absorbed the lead so that lead poisoning was caused. That, of course, is simply following out what Dr. Walker said, that all these metals are more or less soluble in water, and the water in that case in Lowell acted upon the lead pipe. It also acts upon iron to some extent. We have used some galvanized pipe, but without any special advantage so far as we could notice in the results. The pipe which has given us the best results is tin-lined pipe. We have found by experiments that the water acts less upon tin than upon any of the other metals which we could use for pipe.

THE PRESIDENT. What material do you generally use for service pipes now?

Mr. Thomas. It is a tin-lined iron pipe. That is, I presume it is iron pipe; it may be steel.

Mr. Edwin C. Brooks.* Mr. President, I might say in regard to steel pipe, that I find that the weld, where the pipe is butt-welded, is apt to be so hard that it is very severe on the dies, and we found it was hard to cut clean threads on many pieces of steel pipe on that account. I would like to ask Mr. Speller if it is possible that any hardening could take place in the butt-welding of steel pipe? We certainly have had a good deal of trouble from that cause, and we are now using wrought-iron pipe.

Mr. Speller. I think you will find the trouble — if there is any trouble with the threading — is on account of not having a good die. The steel is somewhat harder to thread than iron, but you will not notice it if the die is properly shaped. What you refer to as hardness at the weld may be a slight depression at the weld, which will cause the tooth of the die to catch. When you speak of hardness in steel pipe it usually means toughness.

Mr. Brooks. I have been too long in the business to have tools of the kind you suggest. What I speak of is hardness. The dies that we use are from a reputable firm in Boston. I think you would find it hard to maintain that their dies were not suitable. We found a hardness in the weld; that is, when you tried it with a file it would seem as if it had been actually tempered along the line of the weld. Now, whether anything occurred at that point to tend to harden the steel more than at another point, I do not know; but the trouble was certainly a real trouble and not a fancied one.

Mr. Speller. I have never had any experience with such cases as that, and when I was speaking a moment ago, I was referring to other instances that seemed to correspond with yours. This is the first time I have ever heard of a piece of pipe steel being what you would call hard at the weld. If it is genuine pipe steel it cannot be hard, or we could not weld it. It is one of the purest forms of iron made. It has no tempering quality whatever. You can forge it and chill it in water without hardening in the least. If you have any cases like that on hand we would certainly like to see them.

Mr. Brooks. We discontinued using steel for the very reason

* Superintendent Water Works, Cambridge, Mass.

that there was so much complaint made of the hardness on this line running through lengthwise of the pipe, where the weld was; and it occurred to me whether there might be any possible reason for that in the manufacture.

THE PRESIDENT. Perhaps that wasn't Mr. Speller's pipe, Mr. Brooks. If he had put his name on it you would have known with certainty.

MR. RICHARD A. HALE.* In connection with the water-power development at Lawrence in the earlier days, wrought iron was used as material for the penstocks, the diameters of which varied from 6 to 9 ft. In the last two or three years some changes were made, involving the installing of new wheels, and necessitating a cutting off of the lower portion of some of the penstock. In one mill there was a penstock, I think, 8 ft. in diameter, of wrought iron, which had been in for forty-five years, and an examination of it, where it was cut off, showed no deterioration of the iron that was visible in any way whatever. The iron was bright; there was no pitting. The penstock had been preserved by painting with red lead from time to time when the water was out. There was no pitting either on the inside or on the outside, and no reduction in thickness.

During the last twenty or twenty-five years steel plates have been used for penstocks instead of wrought iron, and observation from year to year of the surface of the interior has shown no indications of marked deterioration. In some cases, where the coating of asphalt has worn off, or whatever paint was put on, there have been some tubercles formed and a slight pitting, but not to any depth; the outside of the penstock does not show that any changes have occurred where it could be examined.

As far as we have seen, there has been no great difference between the steel and the wrought iron. The principal trouble with a steel penstock, and with all penstocks, is to find a proper coating to prevent the water from corroding the interior. Certainly wrought iron, after an experience of forty-five years, has been found to be in excellent condition.

Mr. Brackett speaking of the ring reminded me that recently we took out a wooden penstock, which had been in about fifty

* Principal Assistant Engineer, Essex County, Lawrence, Mass.

years, with iron bands on the outside about an inch and a half to two inches in width and half an inch in thickness, and the wrought iron shows excellent condition, with a bright and fibrous texture, although no coating had been put on. A chemical examination showed a very excellent grade of wrought iron. In all of these cases there were no electrical currents in the vicinity which would produce electrolysis.

Mr. William F. Sullivan.* Our experience with so-called galvanized wrought-iron pipe has shown that the average life of 1-in. pipe is from twenty to twenty-five years, and of $\frac{3}{4}$-in. pipe from fourteen to twenty years, — that is, before it fills so that the service has to be renewed. We find after the filled up pipe is placed in the "scrap" the matter that blocked the flow of water dries and can be knocked or shocked from the interior of the pipe by the aid of a scraper. The old pipe is generally in good condition and may be disposed of as second-hand pipe for about one quarter the cost of new pipe. The users of this second-hand pipe are generally farmers or campers.

We find that the cost of renewing services is inexpensive, owing to the low first cost of the pipe and the character of the excavation — in many instances we are able to drive new services without much trenching. We find that the galvanizing wears off the pipe in a few years, but we feel satisfied that it is worth the slight difference in cost to use galvanized iron pipe. We are not always absolutely certain whether we get the genuine wrought-iron or steel pipe, and as far as my experience goes, it never has seemed of great importance to us on account of the periodic filling up of service pipes.

Mr. George A. Stacy.† I have had about the same experience as that of Mr. Brooks with regard to temper in steel pipe. I don't know about the life of iron or steel, but I think that the dies will last longer on wrought-iron than they will on steel pipe.

The reason I have adopted wrought-iron pipe is because as a general thing when you go into the market you get heavier stock, you get stock that works easier, and it runs more even. We do find that some steel pipe, or pipe which comes to us as steel, is

* Superintendent Pennichuck Water Works, Nashua, N. H.
† Superintendent Water Works, Marlboro, Mass.

much harder and affects the die much more than wrought-iron pipe does. Of course, a dull die is not a very pleasant thing to work with when you want to cut a good thread on anything; but when you get a dull die on a piece of hard steel pipe you have a pretty tough proposition.

I don't condemn steel pipe; I don't know anything about the life of it; but if we have two pieces of pipe, and the pitting is equal, then the light pipe is going first.

Up to the present time my experience with wrought-iron pipe has been every way much more satisfactory than that with steel.

Mr. F. N. Connet. I have not had experience with steel pipe, Mr. President, but there is one question I would like to ask Professor Walker. Some years ago the New York Edison Company had considerable trouble from the depositing of a red material in their boiler feed system, and analysis proved it to be oxide of iron. They used surface condensers, and consequently the same water was used over and over again and no additional oxygen could get into the system. They had been using a small percentage of animal oil in their lubricating oil, and they decided to change over and use mineral oil entirely, after which this trouble ceased.

The explanation which was offered was that a catalytic action had taken place due to the oleic acid present in the animal oil. The idea is that a certain amount of oxygen was absorbed by the oleic acid from the oxide of iron and this was afterward released so that it could immediately combine with more iron and be converted again into oxide of iron, which process could be repeated indefinitely without the necessity of constant renewal of oxygen from outside.

Whether or not this explanation is the correct one, it is certain that when the use of animal oil was discontinued the trouble disappeared. Their feed pipes were four or five inches in diameter and some were the cast iron, some wrought iron, and some cast steel.

Professor Walker. With regard to the word "catalytic," I think that engineer was probably doing as a good many of us do, — when we strike something we don't understand we call it "catalytic action." I don't think it was catalytic action; nor do I think oxide of iron will give up its oxygen when once formed. On any steam heating system which has been running in a closed

cycle for a good while, when you open a radiator pet cock not infrequently you will get enough hydrogen to burn. That is due to the presence of carbonic acid gas in the system. This gas passes up with the steam and is absorbed by the condensed water, forming an acid solution. This reacts on the iron pipe, forming soluble iron carbonate. This returns to the boiler and under the heat there decomposes into iron oxide and sets free carbon dioxide again. I have never heard of, nor do I believe you can have, a cycle in which oxygen acts in this way; when oxygen is taken up by iron it stays combined.

I think it is a fact without question that the animal oil does form free acid when heated with water to a high temperature, and this in itself accelerates corrosion.

Didn't they use any makeup water at all?

Mr. Connet. A very slight percentage.

Professor Walker. A possible explanation is, I think, that they were taking some air into their vacuum system. If you are getting an accumulation of iron oxide it means you are getting additional oxygen. There is no possible escape from that conclusion. Where that oxygen is coming from may be a question. But if they use no makeup water and if their system is closed, that is, if they have no expansion tank, my suggestion would be to look for an air leakage somewhere; because if you use up the oxygen in uniting with the iron at one place, I don't believe that this oxygen can ever get free to unite with any other iron. So I think that the animal oil was the active agent in intensifying the corrosion, but it must have gotten oxygen from somewhere to unite with, in order to form the iron rust.

The President. I am going to ask Mr. Schuhmann and Mr. Speller to answer with regard to the various points which have been made, as far as they can, and I also want them to give us their point of view on this question of marking their pipe, so we can know what pipe we are using. I am also going to ask them if they will not tell us something more about galvanizing and the methods of galvanizing which are used. Dr. Walker has emphasized the importance of having an absolutely uninterrupted coating of zinc, — I don't remember that he mentioned the thickness of it, — but there is a prevalent impression that galvanizing has been

done in the last few years in a very economical manner. I think the members of the Association would like to learn what they can about that.

Mr. Schuhmann. In regard to galvanizing, it is the same thing as with the manufacture of wrought iron, that is, the old way is the best. We have been approached by different inventors who would claim that they could save us anywhere from $3.00 to $5.00 per ton by using their processes, but since the cost of labor is less than 10 per cent. of the cost of galvanizing, while the cost of zinc (spelter) is over 80 per cent., then such a great saving could only be effected by reducing the amount of zinc used, which means a reduction in the thickness of the coating, and for that reason we have declined all such offers, as we do not want to cheapen the goods at the expense of quality. We told these gentlemen that if they could bring us something that would make galvanizing better, we would consider it.

We are using the old process known as the "hot-metal process." The pipes are first pickled in a bath of dilute sulphuric acid, which removes grease, scale, etc. Then they are put in a tank of water to wash off the acid, and after that, put into another tank of dilute muriatic acid. After removal from this tank, the muriatic acid is allowed to dry on the pipes. They are then laid on top of the galvanizing kettle for a short period, to pre-heat them, and are then immersed in the molten zinc in a kettle containing about 60 000 lb. of this metal. They are allowed to remain in there long enough to get the same temperature as the molten zinc, and are then pulled out and held in an inclined position to allow the molten zinc to run out of the inside. Owing to the fact that wrought iron has a rougher surface than steel, the zinc coating will stick to it better and in thicker layers, so that you have not only a better metal as a base, but a heavier coating in addition.

I want to make a few remarks about the statements made by some of the gentlemen in reference to variation in the hardness of steel pipe, and in order to explain that I will have to give a little description of the manufacture of steel. Steel is generally manufactured in large quantities. They make about 15 tons at a blow of a Bessemer converter and anywhere from 25 to 50 tons at one heat of an open-hearth furnace. After the purification is com-

pleted, the steel is poured into large ladles and from them into large ingot molds, forming the so-called "ingots." After it is poured into ingots, the steel melter has finished his work. He cannot do any more to it. But the metal is too hot yet to permit rolling out. It must be allowed to cool first, and during this process of cooling some of the impurities still left in the steel will flock together in the liquid mass, which is technically known as "segregation." This has been fully discussed in some papers before the American Society for Testing Materials, and tests made with large steel boiler plates, by marking them off in squares like a large chess board and taking samples of the different squares, show large variations in the chemical composition as well as physical qualities. So, while it is possible to have hard and soft steel pipe made out of the same ingot, it is also possible that one end of a pipe may be soft, while the other end of the same pipe may be much harder.

Wrought iron is made in small quantities, about half a ton at a time, four men working alternately for about an hour and a half stirring it up so as to thoroughly purify the metal, and in that way the pure iron and the cinder become thoroughly mixed. After the puddle bars have been rolled out, they are cut up into shorter pieces and piled on top of each other, like bricks in a wall. This mixes the iron up similar to the way they mix salt-water taffy with the mixing machines, and the resulting product is of much more uniform quality, just as practical experience has demonstrated. We have not learned of anything yet by which the segregation of steel during the process of cooling can be prevented. Professor Stoughton states that segregated steel will corrode much faster than the same metal in which the impurities are evenly distributed, and he further qualifies the statement by saying that this segregation is always present to some extent in Bessemer and open-hearth steel, and that it is practically unknown in wrought iron.

In regard to the question asked by the President about marking the pipe, would say that we are making experiments with that now, but find it is not as easy as rolling the name in steel rails, for instance. We have tried one way by setting steel dies into the rolls, projecting slightly, so as to roll the name into the pipe. This makes a fairly good mark in black pipe, but after being galvanized

it nearly all disappears again. If the impression is made too deep, then by cutting the pipe right where the name is, it may cause defective threads and consequently a leak. On the other hand, making the impression in the rolls so that the name will project outside the pipe, the planishing rolls will deface it again, or, if left too high, it may require filing off to cut threads. As stated above, we are still experimenting, and hope that before long we will be able to mark our pipe distinctly, because we are not ashamed to put our name on it.

If I understand Professor Walker's statement correctly, he bases his conclusion that there is no material difference between the corrosion of wrought-iron pipe and steel pipe on calculations made by measuring the depth of corrosion on partly corroded pipes under observation for a given time, and also on his erroneous assumption that the corrosion of both metals would have continued at the same ratio at which it started. A large number of tests made by other experimenters have proved that the corrosion of iron and steel is very irregular and erratic. Professor Stoughton, in his article on this subject in the *Engineering Magazine* of July, 1911, states that the rusting of some parts of a piece of steel will be more rapid than of other parts at first, and then conditions may change and the reverse will be the case. Moreover, some specimens will rust more rapidly than others at first and then more slowly. Professor Howe, in a similar paper read before the American Society for Testing Materials (Vol. 6, page 150), gives some very plausible theories as to why corrosion is not uniformly progressive. Such being the case, we feel that conclusions based on calculations of the supposed life of the pipes, by making micrometer measurements of the depth of partial corrosions, are as unreliable as accelerated corrosion tests, which, as we know, are entirely misleading. Fortunately, we have other tests, based on many years of actual experience under ordinary service conditions with wrought iron and steel pipe miles in length, weighing thousands of tons, and where corrosion continued until the holes penetrated the metal, and in all such cases of which a record has been kept the wrought iron was so far superior that it did not require calculations based on measurements to prove the greater durability of wrought iron under average service conditions.

In reference to the remarks made by the gentleman from Springfield, that no matter whether they used wrought-iron or steel pipe for service pipes, the water still retained its red discoloration, and assuming Professor Walker's explanation as correct, that the trouble was in the main, then it is but natural that the material out of which the service pipes were made had no influence on same, for if they had been made of glass it would not have changed the color of the water supplied by the mains.

Mr. Speller. It is hardly necessary to say anything more about galvanizing, as Mr. Schuhmann clearly described the method we are using, that is, the old process of hot galvanizing. Many improvements have been suggested, but any process which promises a reduction in the amount of zinc applied to the surface must be considered with suspicion. No wiping operation should be permitted on galvanized pipe, as it is of the first importance to retain on the surface as much zinc as possible.

Most of the criticisms on steel pipe this afternoon have been on the matter of threading. This has been a surprise to me, as we have not heard much about this trouble of late years. Steel pipe as made direct from the ingot is softer, but at the same time tougher than wrought iron, and, therefore, slightly harder to thread, unless the dies are made with somewhat more rake and clearance than was the case when nothing but wrought-iron pipe was used. Most of the good dies on the market are now properly shaped, and will thread either iron or steel pipe without trouble. We have made a good deal of iron pipe in our time, and now that we are making nothing but soft steel pipe our threading practice is very much better. Fewer bad threads occur, and the speed of cutting has been increased, with a proportional economy in practice. You will find a properly cut thread on steel pipe is stronger and cleaner than can be made on wrought-iron pipe on account of the more homogeneous character of the metal.

Regarding the reference to hard spots in pipe, it would not surprise any one familiar with pipe business if the instance of this referred to turned out on examination to be the kind of wrought-iron pipe our friend Mr. Schuhmann was describing as being made of miscellaneous steel scrap. When steel scrap is bought for the manufacture of wrought-iron pipe (so called) it is impossible to be

sure of its character, and consequently an occasional hard piece is likely to be worked in with the pipe. When steel is made for the manufacture of pipe exclusively, and rolled direct from the ingot, this cannot happen, for if the metal was not uniform or hard in places it would not weld, and would be a loss to the manufacturer. Moreover, no carbon additions are made to steel manufactured for pipe. The iron is refined to the lowest point and is relatively so low in carbon that segregation, if it does occur, can do no harm. So the remedy against possible hard spots is to purchase from the concerns who have control of their raw materials, and who can give satisfactory assurance that sound and uniform metal is put into their product. One important advantage which the steel pipe manufacturer has, where he is making pipe steel exclusively, is, that the product of the steel works is in the hands of a crew of trained experts who can be held responsible for the entire output as to quality. In making puddled iron, on the other hand, with the responsibility divided among a large number of puddlers, the same control is not possible, each man being a law unto himself within rather broad limits. Furthermore, we can speak from our own experience that it is no easy matter to recruit the ranks of the old-time puddlers, as the younger men are inclined to choose a less strenuous job where their skill can be used to better personal advantage.

As to the question of weight and thickness, that is entirely in the hands of the consumer. Steel pipe is now used for such a variety of purposes that it has been found necessary to make more than one standard weight for the same size, and this is also true of wrought iron to a certain extent. By specifying the weight required, and allowing a reasonable margin above or below for variation in manufacture, there should be no trouble in this respect.

Regarding the question of marking pipe with the name of the manufacturer: we have been in the practice of rolling our name on all lap-weld pipe for some time. It is comparatively easy to do this on lap-welded pipe where there is a mandrel on the inside to support the metal. However, marking butt-welded pipe where no mandrel is used is quite another matter. Most users of pipe naturally object to a depression being stamped in the surface, and some also object to having the raised letters on the pipe. I am

glad to say we now have a process for rolling letters in relief on butt-welded pipe which will soon be put into practice so that the consumer may know that he is getting genuine steel pipe, made under a process which insures a maximum of uniformity and durability. By this system of marking it will be impossible to confuse this pipe with that made from steel scrap — or wrought iron.

THE PRESIDENT. Professor Walker, the Association is much indebted to you for coming here this afternoon and for explaining the nature of corrosion so clearly. Mr. Speller is a member of the Association, and I believe the Association has a rule that its members are not to be thanked; but I am sure we have appreciated his being here and doing his duty. Mr. Schuhmann, I think I voice the sentiment of the Association when I thank you for coming here to-day and telling us so much about your pipe and the method of its manufacture, and answering the questions which have been asked concerning it.

MR. RAYMOND W. PARLIN * (*by letter*). Mr. Albert Heard, superintendent and manager of the Washington County Water Company, states that that company completed its water works in July, 1882, at which time it began using one and one-half inch cast-iron B. &. S. pipe for services.

In 1887, after having had considerable trouble with the lead joints in the said pipes, they changed to one-inch extra heavy galvanized genuine wrought-iron pipe and have used the same since with good results. The character of the soil is red clay and lime stone. Some of this style of services have been in since 1882 and are to-day apparently in good condition.

The only trouble they have had is in some cases where the gutter was put in with a base of coal ashes or cinders, in which case the dampness percolating through them causes the pipe to corrode and to eat through for a short distance directly under the cinders, while the pipe on each side of the place has the galvanizing on it intact.

From a superficial examination it would appear that the trouble is caused by the galvanic action set up between the iron and the zinc by contact with the dilute acid from the cinders.

There are about 3 200 services, of which at least 2 400 are of galvanized pipe, and replacements do not average six a year.

* Resident Engineer, Washington County Water Company, Hagerstown, Md.

Mr. Speller (*by letter*). Mr. Schuhmann in referring to conclusions reached from the many comparisons of iron and steel cited has failed to note that the samples were taken from pipe showing all stages of corrosion. (See average depth of pitting, Table 1, page 17.) The experience showed that the same comparisons obtained whether the corrosion was comparatively light or otherwise. In some cases the samples were taken from pipe which had been pitted through.

The depth of the deepest pits were taken in order to have some basis of comparison. No calculations or assumptions were made, nor was there any necessity for such, as we are here dealing with simple facts from specific experiences.

It is only lately that such comparisons could be looked for, as steel pipe is a comparatively modern product, and whatever the merits of the wrought iron prior to the advent of steel pipe, it is surely of more concern to know how steel pipe stands up compared with wrought iron made in our time where both were put in service together, under conditions which have prevailed during the past ten or fifteen years.

Professor Walker (*by letter*). It is evident from what Mr. Schuhmann says (page 34) that he did not understand the nature of the investigation which was conducted or the basis of the conclusion arrived at. Mr. Schuhmann mentions "his [Walker's] erroneous assumption that the corrosion of both metals would have continued at the same ratio at which it started," and then discusses the test as though the samples of pipe had been submerged in water for a few weeks or months. He is right in stating that a short time exposure is an unreliable basis from which to draw a conclusion; but such was here not the case. The pipe examined had been in service from two to seventeen years and the condition after long service is what is reported on, not a short laboratory test such as Mr. Schuhmann cites. As an indication of the condition of the pipe, not as a "calculation," as Mr. Schuhmann assumes, I give the measurement of those samples of pipe which were rusted to practical destruction, that is, where either the iron or the steel showed pits over one tenth of an inch in depth.

TABLE 2.

Sample — Number.	Depth of Pitting.		
	Mean of Ten Deepest Pits.	Deepest Pit.	Least of Ten Deepest Pits.
	Inches.	Inches.	Inches.
W-10 — Iron	.102	.134	.085
W-11 — Steel	.075	.095	.067
W-22 — Iron	.114	.160	.068
W-23 — Steel	.075	.107	.042
W-24 — Iron	.139	.168	.109
W-25 — Steel	.140	.204	.076
X-15 — Iron	.077	.101	.069
X-16 — Steel	.040	.047	.034
X-29 — Iron	.042	.060	.030
X-30 — Steel	.066	.103	.042
X-49 — Iron	.077	.113	.049
X-50 — Steel	.071	.122	.040
X-57 — Iron	.038	.110	.012
X-58 — Steel	.026	.053	.012
X-69 — Iron	.113	.159	.032
X-70 — Steel	.119	.177	.095
X-71 — Iron	.115	.169	.063
X-72 — Steel	.075	.156	.045

SOME THINGS DOMESTIC METERS DO NOT ACCOMPLISH.

BY WILLIAM S. JOHNSON.

[*Read February 14, 1912.*]

Five years ago it was the writer's privilege to present to this Association some facts relating to the consumption of water and the use of meters,* the chief object of the paper being to emphasize the fact that the use of domestic meters does not necessarily mean a low rate of consumption and the lack of meters a high rate, but that there are other conditions which have in many cases a greater influence on the quantity of water used and wasted than the method of charging for it.

In connection with the paper, statistics were presented, including all of the records which could be obtained, some of which showed results quite different from those commonly quoted to show what meters will accomplish. The discussion which followed seemed to indicate that if the figures did not show low consumption with the use of meters, the figures must be wrong.

Since this paper was presented I have had occasion to analyze the consumption of water in several towns, and interesting facts from other places have come to my attention showing even more clearly than the results presented five years ago some of the things which domestic meters do not accomplish, and showing also that any intelligent discussion of the probable saving of water by the introduction of meters should be preceded by a study of the conditions in the town to be metered.

It is very common now to find in a town suffering from a shortage of water, a number of enthusiasts who earnestly believe that the only thing needful is to introduce meters and thus solve the problem of a future water supply by reducing the consumption. The cities of Brockton and Fall River, with a consumption of about 40 gal. per person per day, are invariably cited as examples of

*Journal, N. E. W. W. A., Vol. 21, p. 109.

what can be done in any municipality by the introduction of meters.

In many of these places a study of the conditions shows that any such reduction of the consumption is absolutely impossible. A good example of this is the case of a Massachusetts town where there are perhaps 20 or 25 meters in use, and where there has been a lively agitation for the introduction of meters to relieve the shortage of water. Ten of the consumers already metered use for manufacturing or mechanical purposes enough water to make the average daily consumption in the town 35 gal. per person. The placing of meters upon all of the other 800 or 1 000 service pipes would undoubtedly reduce the consumption of water to some extent, but this town could never be in a class with Brockton, with its consumption of less than 40 gal. per person per day.

Other factors than the use of water for manufacturing purposes, some not so obvious, are almost universally overlooked. The stealing of water from fire-service supplies; leakage from mains and service pipes; and water used for flushing sewers, for drinking fountains, and other public purposes, are large items in the consumption of water, and the finding of one leak or of one case of stealing water may reduce the consumption more than the installation of hundreds of domestic meters.

As far as the saving of water is concerned, if I could not have both, I would choose every time to have some means of measuring the whole supply rather than to have every domestic service provided with a meter. The results accomplished at Holyoke, Southbridge, and other places when it was discovered by means of meters on the main pipes how much water was being used, show what can be accomplished by simply learning the necessity of doing something and having the encouragement of seeing the results of one's labors recorded on the meter chart.

Of course, in pumping systems this does not apply, for an idea can always be obtained — though sometimes a crude one — of the amount of water used by the counter on the pump.

I want to say that I believe most thoroughly in meters, and consider that the only proper way to sell water is by measure, and in calling attention to some of the things which meters do not accomplish I do it as an ardent " meter-man."

Meters do not prevent an increase in the quantity of water used for what may be termed legitimate purposes. This increase in the use of water, which has been referred to many times, is due chiefly to the increase in the number of plumbing fixtures, especially in the less expensive houses, and the increased quantity of water used in the modern fixtures. The rate of increase may be somewhat affected by the use of meters, but only to a slight extent, for householders are not likely to be deterred from the introduction of plumbing fixtures by the fact that the water is paid for by measure. In fact, the increased cost due to additional plumbing fixtures is generally less with meters than it is under fixtures rates.

This natural increase in use of water for domestic purposes is best shown in those places which have been thoroughly metered for many years and where there have been no great demands for water for manufacturing purposes. The increase in the per capita consumption at Brockton, which has been thoroughly metered for many years, was, between 1900 and 1910, 34 per cent. The increase in Fall River, another thoroughly metered city, during the same period, was 22 per cent. In North Attleboro, where all services are metered, the increase was 44 per cent. In Wellesley the increase in that time was 30 per cent., and in Worcester it was 7 per cent.

Comparing the increase in the ten-year period in these places thoroughly metered with places which have very few meters, it will be seen that, although the per capita consumption is generally larger, the percentage of increase is much the same. In Beverly, where only 4 per cent. of the services are metered, the increase was 26 per cent.; in Salem, 20 per cent.; in Danvers, 24 per cent., and in Newburyport, 63 per cent.

There are some unmetered towns in which the increase has been more rapid, such as Peabody, where the consumption increased 87 per cent., due largely to an increased use for manufacturing; but there are also unmetered towns where there has been a considerable decrease, such as Gardner, with a decrease of 34 per cent. in ten years, the reason for which will be given later.

To show the immediate effect of introducing meters the following table has been prepared in which the different cities and towns of Massachusetts, for which records of the consumption are avail-

able, have been grouped according to the increase in the percentage of services metered during the ten-year period from 1900 to 1910, and in the five-year period from 1905 to 1910, and the average increase in the consumption in each group has been obtained.

TABLE 1.

Increase in the Percentage of Services Metered.	From 1900 to 1910.		From 1905 to 1910.	
	Number of Places.	Increase in the Daily Consumption per Person (Gallons).	Number of Places.	Increase in the Daily Consumption per Person (Gallons).
Less than 10.......	24	15	44	6
From 10 to 25.....	14	11	16	1
More than 25......	15	8	18	—11

Meters will never make the consumption in two places the same if the character of the population in respect to their requirements for water are different. Manchester, with all services metered, uses 120 gal. per person per day; Dedham, 129 gal.; and Beverly, with 4 per cent. metered, uses 91 gal. per person per day. These places with large estates owned by wealthy men and with sprinklers in operation continuously during the summer on extensive lawns cannot be expected to have a consumption like that at Fall River, and yet in one of these places I have heard Fall River cited as an example of what might be accomplished there by the general introduction of meters.

In many places one of the reasons why domestic meters will not produce a low rate of consumption is that there is a large quantity of water used for manufacturing or mechanical purposes.

Table 2 gives statistics in regard to the consumption by large consumers in various places in Massachusetts.

Even in the so-called unmetered towns the water used for manufacturing purposes is generally metered and it is easy to determine this element in the consumption, which in many cases is an important one.

TABLE 2.

City or Town.	Population 1910.	Average Daily Consumption per Inhabitant.	Largest Single Consumer Uses:—		Ten Largest Consumers Use:—		Twenty Largest Consumers Use:—	
			Per Cent. of Total Consumption.	Gallons per Day per Inhabitant.	Per Cent. of Total Consumption.	Gallons per Day per Inhabitant.	Per Cent. of Total Consumption.	Gallons per Day per Inhabitant.
Amherst	5 112	..	...	13.7	...	34.4	...	...
Attleboro	16 215	54	2.2	1.2	7.5	4.1	9.6	5.2
Billerica	2 789	39	8.8	3.4	17.8	7.0	20.4	8.0
Brockton	56 878	39	2.0	0.8	8.2	3.2	10.9	4.3
Chelsea	32 452	87	...	...	...	...	21.1	18.4
Chicopee	25 401	..	...	2.7	...	11.2	...	12.5
Clinton	13 075	45	7.3	3.3	22.4	10.2	26.0	11.8
Framingham	12 948	48	11.3	5.5	23.8	11.5	27.2	13.2
Franklin	5 641	61	8.8	5.3	23.4	14.2	26.0	15.8
Gardner	14 699	44	2.4	1.1	10.9	4.8	13.2	5.8
Gloucester	24 398	55	2.5	1.4	9.0	5.0	10.5	5.8
Greenfield	10 427	..	...	27.7	...	40.7	...	46.0
Haverhill	44 115	..	...	3.5	...	7.1	...	8.2
Holyoke	57 730	103	1.1	1.2	7.8	8.1	12.0	12.4
Lawrence	85 892	45	5.6	2.5	14.7	6.6	16.8	7 6
Leominster	17 580	..	...	10.7	...	34.4	...	42.3
Lowell	106 294	51	2.2	1.1	5.2	2.7	6.6	3.4
Lynn and Saugus	97 383	72	5.5	4.0	11.2	8.1	12.4	9.0
Malden	44 404	42	3.2	1.3	10.4	4.4	12.1	5.1

Marlboro	14 579	37	4.5	1.7	17.9	6.7	21.1	7.8
Middleboro	8 214	42	32.0	13.3	37.7	15.7	39.3	16.3
Milford	13 055	51	...	1.0	...	5.0	...	6.9
Milton	7 924	39	1.5	0.6	6.2	2.4	8.8	3.4
Monson	4 758	..	...	1.5	...	...	...	3.3*
Natick	9 866	57	12.2	1.3	9.4	5.4	12.6	7.2
New Bedford	96 652	81	2.5	2.1	15.4	12.5	24.0	19.5
Northampton	19 431	..	...	6.7	...	21.9	...	24.7
Reading	5 818	35	2.2	0.8	8.7	3.1	10.2	3.6
Springfield	88 926	..	...	1.9	...	9.1	...	12.7
Taunton	34 259	63	7.8	4.9	24.4	15.3	26.1	16.4
Weston	2 106	50	2.2	1.1	13.6	6.8	...	...
Winchendon	5 678	30	1.5	0.5	8.3	2.5	10.4	3.2
Worcester	145 986	74	...	...	...	...	19.3*	14.3*

*Total quantity used for manufacturing.

In the town of Peabody, for example, where only 7 per cent. of the services are metered, and the meters are placed only on the large consumers, the average daily consumption amounts to 152 gal. per person, and of this 64 per cent. is passed through the few meters. This amounts to 97 gal. per inhabitant per day.

In the town of Greenfield the quantity of water used by twenty of the large consumers amounts to 46 gal. per inhabitant per day. It would obviously be impossible to bring the per capita consumption to a very low figure in either of these towns by putting meters on all of the domestic services. In many places the rates charged large users of water are so low as to encourage the use by manufacturers of water from the public works rather than from private supplies, being in some cases less than the actual cost of supplying

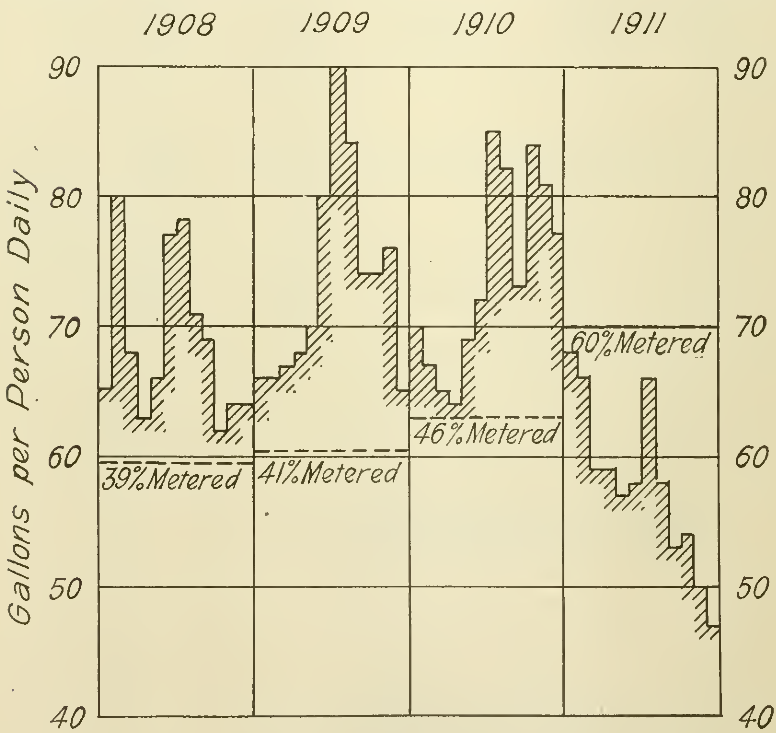


Fig. 1.

Reduction of Consumption by Metering a Single Service.

the water, and what is needed to reduce the consumption in such cases is not the introduction of domestic meters, but the introduction of more equitable water rates.

A better basis for comparing the domestic consumption would be to first deduct the quantity of water used for manufacturing and mechanical purposes. If this were done, it would be found that many of the great differences which appear in the per capita consumption would disappear. Thus, for example, if the consumption of water by the twenty largest consumers were deducted from the total consumption, it would leave in Brockton, where the reported consumption is 39 gal. per person per day, a domestic consumption of 35 gal. per person per day. In Taunton, where the reported consumption is 63 gal. per person per day, there would remain a domestic consumption of 47 gal. per person per day. The town of Peabody would have a domestic consumption of only 55 gal. per person per day instead of 152 gal. as reported. The domestic consumption, after deducting the manufacturing consumption, would be very much more nearly the same in the different places, and some of the places having low consumption, which now serve as examples of what meters will do, would change places with some of the other towns which report larger consumptions.

The quantity of water which is stolen from the pipes cannot be reduced by the introduction of domestic meters, and this item is of considerable importance, as I have had occasion to learn recently.

In a Massachusetts town having about one third of the services metered the consumption has been about 75 gal. per person per day for several years. (Fig. 1.) A little over a year ago the night consumption was so irregular that the engineer at the pumping station could detect it on his pressure gage indicating a heavy draft during certain hours. An investigation showed only one place where there could be any night draft sufficient to cause such irregularities and this was in a factory running all night and supplied with a large connection for fire protection. A meter was placed on this connection and the result was as shown on the diagram. The water had been stolen from the fire service at a rate of more than 200 000 gal. per day.

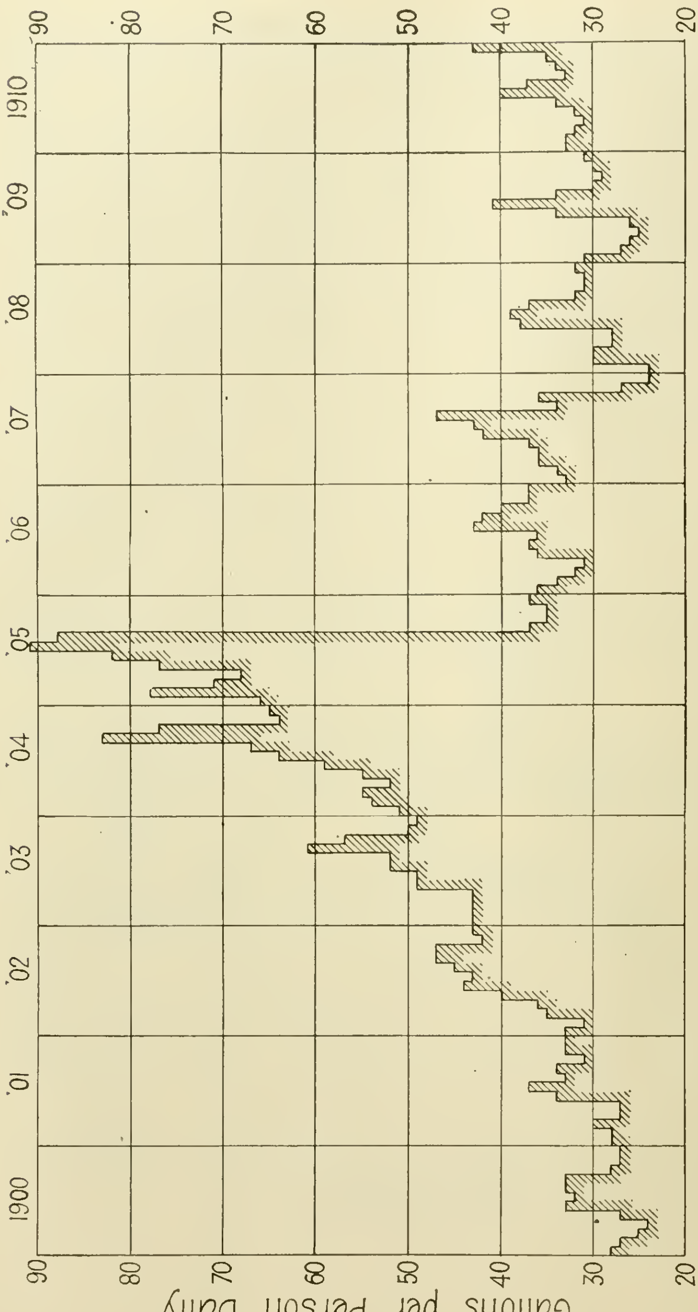


Fig. 2.
Reduction of Consumption by Discovery of a Leak.

Not all of the gain shown on the diagram, however, can be attributed to this one cause. A considerable portion of the saving, especially during the latter part of the year, has been due to the placing of the new meters on services where it was expected they would do the most good instead of placing them only where requested by the consumer, as had been the custom previously. In most towns it is a fact that meters on a quarter of the services, if the services are intelligently selected, will accomplish three quarters of the saving of water which can be expected by metering every service.

Leakage from the mains and service pipes in the streets is another large source of loss of water which domestic meters do not affect. One of the best illustrations of this is shown in Fig. 2. In this town the consumption had been increasing at a rapid rate, and it seemed that an additional supply must be secured. In fact, investigations were already begun when some observant person noticed during the fall of 1905 that more water was coming out of one of the culverts than was entering at the other end, and it was discovered that there was a broken pipe which had been discharging into this culvert for an unknown period. In this town, undoubtedly, Fall River and Brockton were quoted, and it was maintained that the only proper solution of the water-supply problem was the introduction of meters, and yet by the discovery of a leak the consumption was reduced from 80 gal. to 35 gal. per person per day.

Another excellent illustration of what can be done without meters in reducing the consumption of water is found in Gardner, Mass. (Fig. 3.) The superintendent, Mr. Edwin L. Stone, a member of this Association, has given me permission to quote his statement as to the results accomplished.

"The superintendent having died in December, 1908, I was appointed superintendent by the Water Commissioners, March 1, 1909. As I was used to handling a plant which was 95 per cent. metered I naturally thought the consumption very large. It was the custom of the water department to make an inspection every two years and as this was the year for such an inspection a man was sent around to ascertain the number of fixtures and size of families and to find leaky fixtures. He was also armed with an aquaphone and instructed to listen for any unusual noise on the

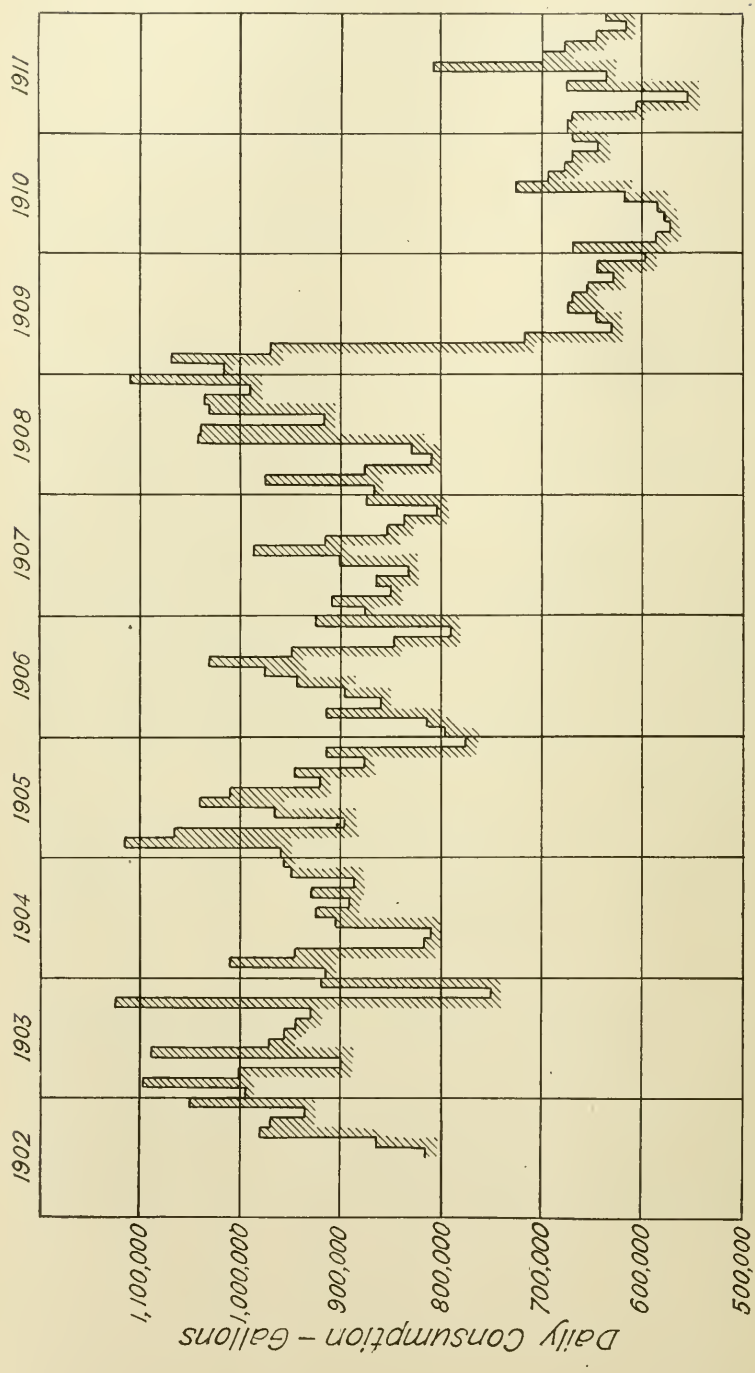


Fig. 3.

Reduction of Consumption in Gardner, Mass., by System of Inspection for Leaks.

service pipes which might indicate leaks. Quite a few leaks were found in this way. Notice was at once sent from the office to have leaky fixtures repaired, and this was followed by another inspection of all leaky fixtures.

"As soon as the weather permitted I made a very careful inspection of all the hydrants and gates and in this way found many leaks in the main pipes and services, which, when fixed, made a big reduction in the water consumption. The result in the first year, nine months of which were under the new conditions, was a saving of 358 000 gal. per day, or a per capita consumption of about 54 gal. The result can be shown better by comparing the years 1908 and 1910, which gives a full year under the old conditions and a full year after the inspection was made

Daily consumption	1908,	1 100 745 gal.	or 71 gal. per capita.
,, ,,	1910,	640 602 ,,	or 43 ,, ,, ,,

Saving, 460 143 gal. per day, or about 42 per cent.

"The leaks that were found and repaired were as follows:

100 to 150 leaky fixtures.
86 outside leaks.
43 joints.
8 pitted wrought-iron pipes.
3 gates.
2 breaks.
12 hydrants.
2 curb cocks.
8 lead connections.
1 $\frac{3}{4}$-in. pipe broken.
6 leaks were found on private fire services.

"I find it quite a problem after reducing the consumption to keep it within bounds. This I do by making a careful study of the consumption at all times, recording each day's consumption on a chart, noting the consumption particularly between 6 P.M. and 6 A.M. I will say, without the aquaphone and a Winslow recording instrument you are lacking the most valuable assistance. Too much value cannot be placed upon the aquaphone when in experienced hands.

"The water saving amounted to 168 000 000 gal. per year. There is no way of placing a value on this water, but taking the cost of our auxiliary pumping at Perley Brook, which is \$24.42 per million, this made a saving to the town of about \$4 100.

"There was a saving in the coal pile at the pumping station of 245 tons, which at \$5.10 amounted to \$1 250, or a total saving of \$5 350 per year.

"Considering that we have only 6 per cent. of our services metered and have a per capita consumption of only 43.5 gal., or 366 gal. per tap, I feel well pleased, and find it a well-paying proposition to keep constantly after the leaks."

The quantity of water used for public purposes is frequently a large percentage of the total supply, and domestic meters do not remedy this. A drinking fountain will consume an enormous quantity of water unless properly regulated. Flush tanks on sewers, which fortunately are not common in this vicinity, use enormous quantities of water. In one city in another state, which is entirely metered, and where the quantity passed through meters was considerably less than half of the quantity pumped, it was found upon investigation that almost as much water was being used in the automatic flush tanks at the dead ends of sewers as was being passed through domestic meters.

A very unusual opportunity to study the effect of meters in a

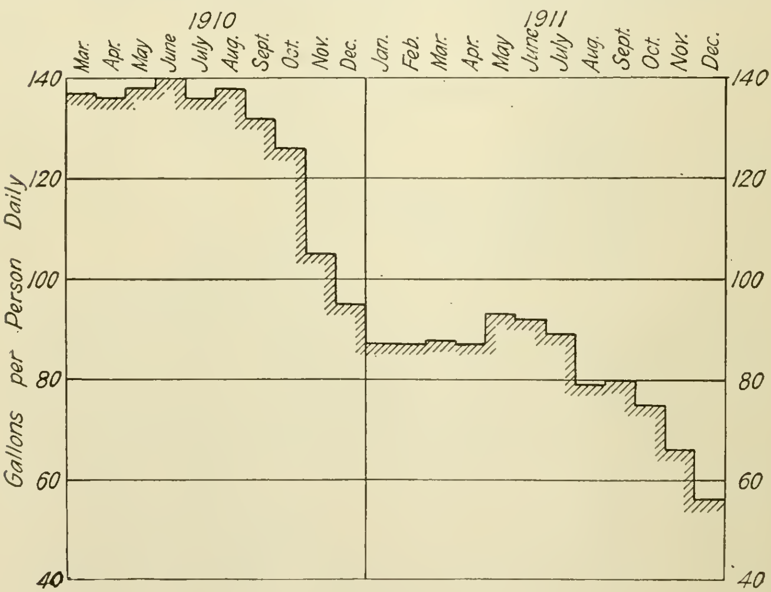


FIG. 4.

REDUCTION OF CONSUMPTION AT SOUTHBRIDGE WITH THE INSTALLATION OF A VENTURI METER.

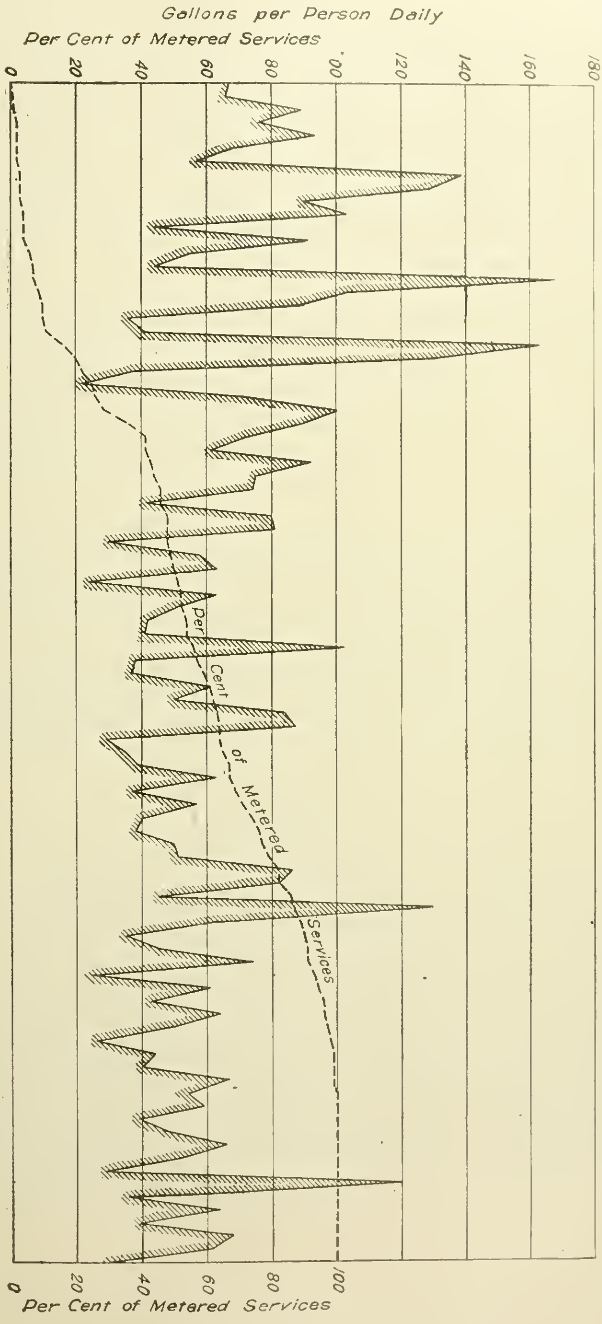

Gallons per Person Daily
Per Cent of Metered Services
0
20
40
60
80
100
120
140
160
180
Per Cent of Metered Services
Per Cent of Metered Services
Gallons per Person Daily

FIG. 5.

town previously entirely unmetered is found in Southbridge. (Fig. 4.) This town is supplied by gravity, and until early in 1910 there were practically no meters in operation and there was no means of measuring the total quantity used by the town. In May, 1910, a Venturi meter was put into operation, and it was found that the consumption was nearly 140 gal. per person per day. This led to an inspection, which revealed several large leaks, the most of which were in factory yards. As a result of the inspection alone, the consumption was reduced from 140 gal. to 90 gal. per person per day.

It was then decided to meter the services, and, as soon as the meters could be placed, every service in town was supplied with a meter. It is too early yet to ascertain the effect of this wholesale introduction of meters, but the consumption in December, 1911, was 56 gal. per person per day instead of 90 gal., which was the consumption after the inspection but before the introduction of meters.

The total reduction in consumption has amounted to more than 1 000 000 gal. per day, 60 per cent. of which was due to inspection stimulated by the introduction of a Venturi meter, and 40 per cent. was due to domestic meters.

For the purpose of showing in a general way the relation between the percentage of metered services and the per capita consumption I have plotted the consumption for 1910 in all Massachusetts cities and towns having consumption records, in order of the percentage of services metered. (Fig. 5.)

The places on the left of the diagram have very few meters, while those on the right are thoroughly metered. As would be expected, the high points occur generally among the places having few meters and those on the right among the metered towns can be accounted for. For example, the two highest points on the right of the diagram represent Manchester and Dedham, where a high consumption would be expected whether metered or unmetered.

Excluding the abnormal points the average consumption in the unmetered places is about 75 gal. per person per day, and in the metered cities and towns about 50 gal. It will be noticed that the reduction in consumption is much more rapid with the first 50 per cent. of services metered than with the last 50 per cent.

When we see side by side figures showing the total quantity of water used and the quantity passed through meters in those places where practically all of the services are metered, and find that generally only 60 per cent. and sometimes as little as 30 per cent. of the water is accounted for, it is plain that there is something yet to be done which the meters have not accomplished.

The slip of the pumps, and under-registration of meters, may account for some of the discrepancy, but when allowance is made for all of this, there still remains a large quantity of water which cannot be accounted for. This is where the efforts of the officials in those places which are already metered should be directed, and I have no doubt that as much can be accomplished in reducing the consumption in some of the towns which are already metered as in some of the places which are unmetered.

It seems to me that the only way by which we can avoid deceiving ourselves and others in regard to what meters are accomplishing is to separate the consumption of water into different classes, as was urged by Mr. Cole in a paper presented to the Association in 1910,* determining the quantity used for manufacturing, mechanical, and other purposes, and the quantity used for strictly domestic purposes. Then, instead of feeling that we have done our whole duty by putting meters on all services, let us reduce the "per centage unaccounted for" as has been done in some of the cases cited.

DISCUSSION.

Mr. Dexter Brackett.† This is a subject with which I have dealt for many years, and in which I have taken great interest. I agree with the speaker that the use of water meters will not prevent entirely the waste of water, or even as much as has been in many cases claimed by the advocates of water meters. I do, however, thoroughly believe that water meters should be used in connection with all water supplies, and they should be installed with the construction of the works. And, further, it is very desirable in works of any considerable size that the whole district

* Journal N. E. W. W. A., Vol. 24, p. 636 (appointment of committee), and Vol. 25, p. 66 (Mr. Cole's paper).

† Chief Engineer, Metropolitan Water Works, Mass.

may be divided into sections, so as to conveniently measure the quantity of water used on different portions of the works. In this way the quantities which are used and wasted, both by the individual takers and from street mains, can be determined.

The conditions in different places are, as the speaker has stated, often very different. The city of Melrose may be considered as affording a fairly good example of the results which may be accomplished by the use of meters. In that city the per capita consumption in 1907 was 118 gal., and by the introduction of meters, and without any special effort to find leaks in the street mains, the consumption was reduced to 64 gal. in 1910, a saving of 54 gal. per capita. There is still opportunity for a considerable saving from leaks from the mains.

The adjoining town of Stoneham has several times largely reduced its consumption by finding leaks in the street mains, and at one time made a saving of about 300 000 gal. I say at one time, because subsequently the leakage from the street mains has increased, and has again been reduced in the same way, showing that there is need of constant vigilance.

Regarding the use of Venturi meters, I believe them to be very efficient instruments for the measurement of water, and very useful in connection with the detection of leaks, as by their use it is very easy to judge as to whether more water is being used during the night than is due to the proper consumption.

We have never made any careful scientific tests to determine the accuracy of the Venturi meters. There are sixty or more in constant use, measuring all the water that is used by the several cities and towns in the Metropolitan District. The water which is drawn from the reservoirs through the aqueducts is measured by means of current meters. A second measurement is made of the water by the displacement of the pumps at the pumping stations, and a third measurement is made by the several Venturi meters through which the several cities and towns are supplied. There are differences, due to leaks from some portions of our supply mains, which are not metered, but the three measurements from month to month agree within two per cent. I do not think there has been any month when it has been more than that, although possibly it may have been up as high as three per cent. This is

not a strictly scientific method of testing the meters, but at the same time it is a practical test, and it shows that the meters are not far from correct, or, at any rate, if they are not correct, all the other measurements agree with them.

Mr. Allen W. Cuddeback.* It seems to me the primary object of domestic meters, and of all meters, is not necessarily to reduce the consumption of water, but rather to properly distribute the cost of water where it belongs. If the consumption is large and the domestic meters do not account for their proper proportion of the water, it puts the operating department on guard, and starts search for waste. Another important point, which has been brought to my attention during the recent cold spell, is this: We supply three towns. Two of them are 50 per cent. metered and the other is 100 per cent. metered. The consumption in the towns 50 per cent. metered has increased 50 per cent. in the recent cold spell, while the consumption in the town 100 per cent. metered has not increased at all. In this climate this is an important consideration, for often in periods like this the capacity of any plant may be overtaxed, where meters are not installed.

Mr. Brackett. I would like to ask the last speaker whether in the town where there was no increase in consumption the works had not been recently installed, that is, within the last ten years, or if the meters were not installed at the construction of the works.

Mr. Cuddeback. The meters were not installed at the construction of the works, but were installed only a few years afterwards; and the plumbing in the towns only 50 per cent. metered is somewhat older than in the town 100 per cent. metered. That is, the town 100 per cent. metered is a newer town.

Mr. Brackett. The results in the different cities and towns where we have made observations show that where meters have been applied to old plumbing, in Boston, for example, the householder will let the water run if the plumbing is liable to freeze, because it is cheaper to pay for the water than it is to pay for removing the plumbing. As an illustration of the effect of cold weather, the use of water in the Metropolitan District increased

*Engineer and Superintendent, Passaic Water Company, Paterson, N. J.

from 103 083 400 gal. in December, which was comparatively warm, to 136 631 000 in January, which was a cold month, an increase of 33 500 000 gal. per day.

Mr. Cuddeback. What percentage is that?

Mr. Brackett. Approximately 33 per cent.

Mr. Frank L. Fuller. Was that all due, Mr. Brackett, to allowing the water to run to prevent freezing?

Mr. Brackett. I know of no reason why the consumption should have been any larger in January than in December other than the effect of cold weather.

Mr. Fuller. Mr. President, during the last cold days I have allowed the water in my house to run a little at night. I have taken a reading in the morning and compared it with a reading during twenty-four hours when there was no water running to waste, and found a very slight increase. That may be due to the water not being registered, but whether it is or not it shows me that it is unnecessary to let a great deal of water run to prevent pipes freezing.

In regard to a simple method of finding leaks in the street mains, especially when works are new, I would like to say that after the pipes have been filled and the pressure put on to the system, a gage may be connected with a hydrant and then the section in which the hydrant is located shut off. When the last gate is shut, see whether the pressure is maintained, or whether it gradually falls off. If there is a leak of much consequence the pressure will reduce very quickly; if it is small, not so fast; if there is no leak at all it will be some time before there will be much decrease in the pressure. I suppose after the water has been let on to the houses, by keeping the faucets closed, the result would be the same. Certainly a leak of large or even of moderate size could be quickly detected. In a large city it would be a slow process, but in the ordinary town it would take only a short time to do it.

Mr. George A. Carpenter.* Mr. President, I have been impressed on several occasions with the effect of the different methods used in computing per capita consumption. I assume that the usual way is to take either the plunger displacement, which many of us have oftentimes found to be greatly in error, or the meter measurements from a large Venturi meter, and to divide

* City Engineer, Pawtucket, R. I.

these figures by the total population, thereby arriving at the per capita consumption.

Ten years ago, when investigating this subject, I was rather surprised to find how low were the figures of actual per capita consumption when arrived at by a different process. For example, studying a city in 1900, taking the census enumerators' returns by districts, the actual metered consumption of the several houses in these districts, and dividing this metered consumption by the actual population, I found a domestic consumption of 16.3 gal. per capita, leaving out the manufacturing consumption. Taking the manufacturing consumption into account, the per capita consumption became 41.8 gal. per day. Based on plunger displacement and the total population, the consumption figured 90 gal. per capita per day.

Ten years later, or in 1910, when making a second study of this same city, and following the same methods as before, the actual domestic consumption was found to be 19 gal. per capita per day, and including the water used for manufacturing purposes it became 58 gal. per capita per day. At the same time the total water consumption for the city, as measured by a Venturi meter and dividing by the population served, was 80 gal. per capita per day.

The above figures show how large a proportion of the figures reported as per capita consumption applies to that portion of the water which passes through drinking fountains, flush tanks, leakage from mains and services, or escapes in ways of which we have, at present, very little definite information.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 13, 1911.

The President, Mr. Allen Hazen, in the chair.
The following members and guests were present:

Honorary.

Mr. F. P. Stearns. —1.

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, T. H. Barnes, F. D. Berry, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, Dexter Brackett, E. C. Brooks, James Burnie, J. C. Chase, G. E. Crowell, A. W. Cuddeback, E. D. Eldredge, G. F. Evans, G. H. Finneran, F. F. Forbes, A. N. French, F. J. Gifford, A. S. Glover, Clarence Goldsmith, J. N. Goodell, F. W. Gow, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, Allen Hazen, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, Morris Knowles, N. A. McMillen, H. V. Macksey, A. E. Martin, F. E. Merrill, William Naylor, G. A. Nelson, F. L. Northrop, T. A. Peirce, H. E. Perry, J. L. Rice, L. C. Robinson, P. R. Sanders, H. W. Sanderson, A. L. Sawyer, C. W. Sherman, G. H. Snell, F. N. Speller, G. A. Stacy, T. V. Sullivan, H. A. Symonds, C. N. Taylor, L. A. Taylor, H. L. Thomas, R. J. Thomas, E. J. Titcomb, D. N. Tower, C. H. Tuttle, W. H. Vaughn, G. E. Winslow. — 66.

Associates.

Ashton Valve Company, by C. W. Houghton and H. W. Ashton; Builders Iron Foundry Company, by F. N. Connet and A. B. Coulters; Darling Pump and Manufacturing Company, Ltd., by H. H. Davis; George E. Gilchrist Company, by G. E. Gilchrist; Goulds Manufacturing Company, by R. E. Hall; *Engineering Record*, by I. S. Holbrook; Hersey Manufacturing Company, by A. S. Glover, H. D. Winton, and W. A. Hersey; Fred A. Houdlette & Son, Inc., by M. S. Kahurl; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Co., by C. F. Glavin; Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin,

and H. L. Weston; Neptune Meter Company, by R. D. Wertz; Pittsburg Meter Company, by R. A. Lester; Platt Iron Works Company, by F. H. Hayes; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Thomson Meter Company, by E. W. Shedd; Walworth Manufacturing Company, by E. H. Rice; R. D. Wood & Co., by E. J. Lame; Henry E. Worthington, by Samuel Harrison. — 30.

GUESTS.

J. G. Hill and R. W. Van Tassell, water commissioners, Lowell, Mass.; George Smith and John G. Howland, Springfield, Mass.; S. W. Hildreth, water commissioner, and J. L. Hyde, town engineer, Westfield, Mass.; F. M. Griswold, National Fire Prevention Association, New York City; B. E. Warren, Nashua, N. H.; Harry Barker, *Engineering News*, New York City; E. J. Mishler and George Schuhmann, Reading, Pa.; George H. Perry, E. F. Hughes, and Prof. W. H. Walker, Boston, Mass.; A. W. Powers, Cohoes, N. Y. — 15.

The Secretary read applications for membership, duly approved, from:

Active: Charles H. Ross, superintendent Waterloo Water Company, Waterloo, N. Y.; Alfred H. Young, superintendent Jewett City Water Company, Jewett City, Conn.; W. E. Miller, C. E., Madison, Wis., engaged in railway, gas, and water engineering; John L. Hyde, Westfield, Mass., engaged in municipal engineering.

Associate: Eddy Valve Company, Waterford, N. Y., manufacturers of valves, hydrants, etc.

On motion of Mr. Sherman, the Secretary was directed to cast one ballot in favor of the applicants, and he having done so they were declared duly elected members of the Association.

Mr. William H. Walker, professor of chemical engineering, Massachusetts Institute of Technology, presented a paper entitled, "An Investigation of the Relative Life of Iron and Steel Pipe as Found in Actual Service." The discussion was opened by Mr. F. N. Speller, metallurgical engineer, Pittsburg, Pa., representing steel-pipe manufacturers, and he was followed by Mr. George Schuhmann, vice-president and general manager of the Reading Iron Company, representing the manufacturers of wrought-iron pipe, and by Mr. Kahurl, representing the new

product manufactured by the American Rolling Mills Company. The discussion was also participated in by Mr. Smith of Springfield, Mr. Dexter Brackett, Mr. Robert J. Thomas, Mr. Edwin C. Brooks, Mr. Richard A. Hale, Mr. William F. Sullivan, Mr. George A. Stacy, Mr. F. N. Connet, and Professor Walker; and Mr. Schuhmann and Mr. Speller closed the discussion.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, Mass., January 10, 1912.

The President, Mr. Allen Hazen, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, Randolph Bainbridge, F. A. Barbour, H. K. Barrows, C. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, James Burnie, G. A. Carpenter, C. E. Chandler, H. H. Chase, P. M. Churchill, R. C. P. Coggeshall, M. F. Collins, J. H. Cook, John Doyle, E. R. Dyer, J. L. Dower, E. D. Eldridge, B. R. Felton, G. H. Finneran, J. H. Flynn, F. L. Fuller, Clarence Goldsmith, F. J. Gifford, A. S. Glover, J. M. Goodell, F. H. Gunther, R. K. Hale, E. A. W. Hammatt, W. E. Hannan, A. R. Hathaway, T. G. Hazard, Jr., Allen Hazen, D. A. Heffernan, M. F. Hicks, H. K. Higgins, C. L. Howes, W. S. Johnson, A. W. Jepson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, Morris Knowles, E. E. Lochridge, F. A. McInnes, S. H. McKenzie, W. A. McKenzie, N. A. McMillen, A. E. Martin, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, E. L. Northrop, T. A. Peirce, W. J. Sando, C. M. Saville, J. Waldo Smith, Sidney Smith, G. H. Snell, G. A. Stacy, C. T. Treadway, W. F. Sullivan, J. A. Tilden, C. H. Tuttle, W. H. Vaughn, J. H. Walsh, L. R. Washburn, R. S. Weston. — 77.

Associates.

Anderson Coupling Company, by C. E. Pratt; Builders Iron Foundry, by F. N. Connet and A. B. Coulters; Chapman Valve Manufacturing Company, by Robert Shirley and H. L. DeWolfe; Goulds Manufacturing Company, by R. E. Hall; *Engineering Record*, by I. S. Holbrook; Darling Pump and Manufacturing Company (Ltd.), by J. L. Hough and H. H. Davis; F. H. Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by

Albert S. Glover, J. A. Tilden, and W. A. Hersey; Kennedy Valve Company, by F. C. Flinn; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Norwood Engineering Company, by H. M. Hosford and C. E. Childs; Rensselaer Manufacturing Company, by C. L. Brown and F. S. Bates; A. P. Smith Manufacturing Company, by F. L. Northrop; Union Water Meter Company, by Edwin P. King and E. K. Otis; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Waldo Bros., by H. E. Browne; Water Works Equipment Company, by W. H. Van Winkle; R. D. Wood & Co., by C. R. Wood and W. M. Simmons. — 32.

Guests.

S. Pitcher, Worcester, Mass.; W. G. Newhall, Portland, Me.; I. W. Flower, Roe Stephens Manufacturing Company, Detroit, Mich.; H. M. Lofton, general manager Columbian Iron Works, Chattanooga, Tenn.; George E. Felber, Pittsburg Valve Company, Pittsburg, Pa.; W. L. Sharpe, chairman, and Albert S. Benson, chemist, East Greenwich, R. I.; Prof. Kendnon and A. J. Loepsinger, Providence, R. I.; Thomas T. O'Connell, water commissioner, Wakefield, Mass.; George W. Bowers, Lowell, Mass.; A. C. Dickerman, Edward C. Sherman, Frederick A. Cole, and Edward F. Hughes, Boston, Mass. — 15.

The President then introduced Mr. David I. Walsh who made a brief address to the Association.

The Secretary presented applications for active membership, properly endorsed and represented by the Executive Committee, from the following:

Lewis L. Wadsworth, Winchester, Mass., engaged in construction of fortifications, power houses, water and sewer works, for the Federal Government, and in building concrete bridges and in general work; Paul Hansen, University of Illinois, Urbana, Ill., engineering assistant, Massachusetts State Board of Health, chief engineer Ohio State Board of Health, state sanitary engineer of Kentucky, and at present engineer of the Illinois State Water Survey; Hervey A. Hanscom, West Medford, Mass., has been engaged in construction of Metropolitan Water Board's mains, Springfield steel main, Medway, Norton, and Barnstable complete water systems, and other New England plants; Herbert F. Salmonde, Westfield, Mass., has been engaged as chemist, Sanitary

District, Chicago, Ill., chemist Board of Health, Chicago, Ill., and at present chemist West Parish Filters (Springfield Water Works), Westfield, Mass.; Harington P. Stearns, Far Rockaway, N. Y., with the Queens County Water Company; Sam H. Pitcher, Worcester, Mass., assistant engineer city of Worcester.

On motion the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

The Secretary read the following communication:

WATER DEPARTMENT,
BANGOR, ME., January 8, 1912.

MR. WILLARD KENT, *Secretary*
N. E. Water Works Association,
Tremont Temple, Boston, Mass.

Dear Sir, — I have been unable to secure any data from my own proceedings or from those of my father in regard to the effect of an alternating electric current on a pipe, from the standpoint of electrolysis. We have had the matter before us for some time, and have not come to any definite decision. Some state that they consider it as dangerous as the direct, and others claim it is harmless, and the greater number does not know.

Can you give me any information, or refer me to any one who can? Thanking you in advance for your kindness, I remain,

Yours very truly,
HAROLD H. SINCLAIR.

THE PRESIDENT. Is there any one who can inform Mr. Sinclair upon this important point? The alternating current is coming into fashion, and it is something we shall have to investigate.

The following reports of the officers of the Association were received:

REPORT OF THE SECRETARY.

Mr. President and Gentlemen of the New England Water Works Association, — Your Secretary submits the following report of the changes in the membership and general condition of the Association for the year ending December 31, 1911.

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	692	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	†4 566.84	‡3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	†7 237.60	‡2 719.05
1911	Allen Hazen	680	58	12	750	Gloucester, Mass.	Sept. 13–15, '11	6 440.90	†6 279.72	‡2 880.23

* Deceased. † Not including December Journal and reprints. ‡ Does not include $1 815 invested in bonds.

MEMBERSHIP.

The present membership of the Association is 750; that of one year ago was 747, a gain of 3 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows.

MEMBERS.

January 1, 1911.	Honorary members	13			
	Deceased	1			12
January 1, 1911.	Total members		678		
	Withdrawals:				
	Resigned	18			
	Dropped	27			
	Died	9	54		
				624	
	Initiations:				
	January	2			
	February	5			
	March	9			
	April	7			
	June	7			
	September	10			
	November	2			
	December	4	46		
	One member elected in 1910, but qualified in 1911		1	47	
	Reinstated:				
	Members dropped in 1911		9	9	
					680
January 1, 1911.	Total associates		56		
	Withdrawals:				
	Resigned		2	54	
	Reinstated:				
	Associate resigned in 1909		1	1	
	Initiations:				
	September	2			
	December	1		3	
					58
January 1, 1912.	Total membership				750

The Secretary has received $6 249.71, which has been paid to the Treasurer, and has certified for payment bills amounting to $3 349.86.

A statement of the receipts, expenditures, accounts receivable and bills payable will be found in detail in the report of the Treasurer.

Respectfully submitted,

WILLARD KENT, *Secretary.*

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$191.19
Initiation fees	$223.00	
Dues	2 871.00	
Total received from members		3 094.00
JOURNAL:		
Advertisements	$1 763.75	
Subscriptions	183.00	
Sale of JOURNALS	279.25	
Sale of Reprints	40.89	
Total received from JOURNAL		2 266.89
Miscellaneous receipts:		
Sale of "Pipe Specifications"	$61.80	
Dinners	821.00	
Sundries	6.02	
Total miscellaneous receipts		888.82
Total receipts		$6 440.90

Expenditures.

JOURNAL:	
Advertising agent, commission	$271.50
Plates	146.17
Printing	2 117.06
Editor's salary	300.00
Expense	52.19
Amount carried forward	$2 886.92

Amount brought forward		$2 886.92	
Reporting		58.25	
Reprints		222.25	
Envelopes		28.50	
Miscellaneous		13.00	
			$3 208.92
Office:			
Secretary, salary		$150.00	
Expense		46.27	
Assistant Secretary, salary		600.00	
Expense		139.26	
Rent		300.00	
Printing		12.50	
Membership list		186.25	
Stationery		84.86	
Envelopes and postage		134.60	
Library		6.25	
Miscellaneous		24.00	
			1 683.99
Meetings and Committees:			
Stereopticon		$68.66	
Dinners	$830.00		
Cigars	57.90		
Music	87.00		
		974.90	
Badges		55.50	
Circulars		153.50	
			1 252.56
Treasurer's salary and bond			67.50
"Pipe Specifications"			55.00
Miscellaneous expenses			11.75
Total expenses			$6 279.72

The Auditing Committee submitted the following report:

Boston, Mass., January 9, 1912.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

Respectfully submitted,

GEORGE H. FINNERAN,
ALBERT L. SAWYER,
JOHN H. WALSH,
Auditing Committee.

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,
In account with the New England Water Works Association.

RECEIPTS.

1911.			
Jan. 1.	Cash on hand		$2 719.05
	Received of Willard Kent, Sec'y		6 249.71
	Interest on bonds and deposits		191.19
			$9 159.95

EXPENDITURES.

Bills paid		$6 279.72
BALANCE ON HAND.		
People's Savings Bank	$1 874.56	
Mechanics Savings Bank	936.36	
First National Bank	66.30	
Liberty Trust Co.	3.01	2 880.23
		$9 159.95

ASSETS AND LIABILITIES.

ASSETS.

Cash, balance in banks		$2 880.23
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R., 4%, due May 1, 1931. Book value, $1 815. Market value		1 865.00
Accounts receivable:		
Advertising	$598.75	
Sale of JOURNALS	7.00	
Reprints	14.00	
Specifications	.60	620.35
		$5 365.58

LIABILITIES.

Accounts payable:		
Secretary's salary and expenses	$55.00	
Secretary's incidentals	21.44	
December JOURNAL and reprints	305.26	
Editor's salary and expenses	82.00	
Reporting	81.50	
Rent	100.00	
		$645.20
Surplus		4 720.38
		$5 365.58

READING, MASS., January 9, 1912.

LEWIS M. BANCROFT, *Treasurer.*

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 10, 1912.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1911.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1911, and which are consequently not included in the Treasurer's statement); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat smaller in total pages and pages of text than that of several preceding years.

Illustrations. — The total cost of illustrations for the year, including printing, has been $270.12, or 10.3 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge, and additional reprints, when desired, at the cost of the paper and press work. The net cost to the Association for reprints has been $127.20. There have been no advance copies of papers prepared during the year.

Circulation. — The present circulation of the Journal is:

Members, all grades	750
Subscribers	61
Exchanges	29
Total	840

an increase of 13 over the preceding year. Journals have also been sent to 48 advertisers.

Advertisements. — There has been an average of 27 pages of paid advertising, with an income of $1 763.75, a slight increase over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $61.80 have been sold. One thousand copies have been printed, at a cost of $55.00, representing a net gain of $6.80 for the year. The net gain up to a year ago had been $207.25, so that the total net gain from this source to date is $214.05. There are still about 582 copies of specifications on hand, or about $58.20 worth if sold at retail.

The Association has a credit of $4.61 at the Boston Post-Office, being the balance of the money deposited for payment of postage upon the Journal at pound rates.

There are no outstanding bills, on account of the JOURNAL, which are not included in these tables.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1911.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Membership Changes.	Index.	Advertisements.	Cover and Contents.	Inset Plates.	Total.	Total Cuts.
1	March	144	45	189	—	—	32	4	9	234	26
2	June	87	7	94	—	—	32	4	5	135	5
3	September . . .	107	15	122	2	—	32	4	8	168	22
4	December . . .	65	5	70	1	6	32	4	4	117	4
	Total . . .	403	72	475	3	6	128	16	26	654	57

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1911.

Receipts.		*Expenditures.*	
From advertisements . . .	$1 763.75	For printing JOURNAL . .	$1 440.31
From sale of JOURNAL . .	279.25	For printing illustrations .	97.75
From sale of reprints . . .	47.05	For preparing illustrations,	172.37
Subscriptions	183.00	For editor's salary	300.00
		For editor's incidentals . .	31.94
	$2 273.05	For advertising agent's commissions	269.50
Net cost of JOURNAL . . .	352.82	For reporting	139.75
		For reprints	174.25
	$2 625.87		$2 625.87

TABLE No. 3.

Comparison between Volumes XVII to XXV inclusive, Journal of the New England Water Works Association.

	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.	Vol. XXV. 1911.
Average edition (copies printed)	1 200	900	900	900	1 085	1 000	1 000	1 150	1 000
Average membership	587	596	625	665	693	699	710	732	752
Circulation at end of year	656*	667	705	767	785	780	802	827	840
Pages of text	430	491	587	495	500	500	459	643	475
Pages of text per 1 000 members	733	824	939	745	722	715	646	880	632
Total pages, all kinds	619	794	784	662	669	681	627	808	654
Total pages per 1 000 members	1 051	1 332	1 254	995	964	976	884	1 090	870
Gross Cost:									
Total	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15	$3 490.81	$2 625.87
Per page	4.38	3.69	4.17	3.88	3.95	4.01	4.97	4.32	4.02
Per member	4.61	4.91	5.23	3.87	3.82	3.91	4.39	4.78	3.50
Per member per 1 000 pages	7.46	6.18	6.67	5.85	5.70	5.88	7.00	5.90	4.09
Per member per 1 000 pp. text	10.72	10.00	8.91	7.81	7.62	8.02	9.56	7.44	7.36
Net Cost:									
Total	$770.62	$648.11	$1 072.95	$387.96	$483.15	$131.06	$789.98	$1 334.06	$352.82
Per page	1.25	.82	1.37	.58	.72	.19	1.26	1.65	.54
Per member	1.31	1.09	1.72	.58	.70	.19	1.11	1.82	.47
Per member per 1 000 pages	2.12	1.30	2.20	.88	1.04	.28	1.78	2.25	.55
Per member per 1 000 pp. text	3.05	2.22	2.93	1.18	1.39	.39	2.43	2.83	.98

* Exclusive of three hundred sample copies.

On motion of Mr. Coggeshall it was voted that the reports of the Secretary, Treasurer, Auditing Committee, and Editor be received and placed on file.

The President then called for the report of the Committee "to look after and keep track of legislation and other matters pertaining to the Conservation, Development, and Utilization of the Natural Resources of the Country," Mr. M. N. Baker, chairman.

Report of Committee on Conservation, Development, and Utilization of Natural Resources.

Mr. M. N. Baker. *Mr. President and Members of the Association,* — The committee has no very specific report to make. In fact, its name has been sufficient to weight it down so that it has been unable to do anything for several years past. You are all quite as familiar as are the members of the committee with the conservation movement, and nothing has come up which it has seemed necessary for the committee to lay before you at this time.

The President. The next business is the report of the Committee "to prepare a Standard Specification for Fire Hydrants," Mr. H. O. Lacount, chairman.

Mr. George A. Stacy. Unfortunately, Mr. Chairman, Mr. Lacount is sick and unable to be present, but we expect a messenger from him with a document that we will desire to present, in addition to the report which has been submitted in print.

It is very unfortunate that just at the time when we have reached the climax of this long-drawn-out work the chairman cannot be here, for he has done a very large amount of the work.

The President. We will pass the consideration of the report of the Committee to Prepare a Standard Specification for Fire Hydrants, and I will call for the report of the Committee "on Uniformity of Hose and Gate Nuts and Direction of Opening," Mr. Frank L. Fuller, chairman.

Report of Committee on Uniformity of Hose and Gate Nuts and Direction of Opening.

Mr. Frank L. Fuller. Mr. President, Mr. Lacount called me up about an hour before I left for this meeting in regard to this matter, and I told him that it seemed to me that the work of the Committee on Uniformity of Hose and the Direction of Opening of Hydrants and Gates was covered by the report which the Committee on Standard Specification for Fire Hydrants had made, and I think that is true. It seems to me that the Committee on the Uniformity of Hose and Gate Nuts, etc., has really done its work and ought to be discharged from further service, for if there is anything further in this matter it will come up under the work of the new committee.

On motion it was voted that the report of the committee be accepted and the committee be discharged.

The President. The next matter is the report of the Committee "on Water Consumption and Statistics Relating Thereto," Mr. Leonard Metcalf, chairman.

Report of Committee on Water Consumption and Statistics Relating Thereto.

Mr. Leonard Metcalf. Mr. Chairman, I regret that your committee is not ready yet to make a report to you upon its work. We have gotten together quite a lot of material, but we regret to say that the material is not of the sort which we had hoped to get. I think all of you will appreciate the difficulties of the problem of getting records of this sort sufficiently comprehensive to be significant; and the committee — or at least I, for one — have come to the conclusion that we will be able to do more effective work — in fact, we think we can only present to you material of value — by taking the records of a certain number of plants, a few plants, and putting enough study on to those to get some fundamental facts.

Therefore, your committee asks that it may be continued another year, and takes this opportunity to ask that any of you

who may feel that you have within your company records, or the records of the plant which you are operating, material which could be worked up at an expense of time and money, perhaps, but material which is available, you would advise the committee of this fact, so that we may see if we cannot put the necessary work upon plants where we know the material is available.

I might say that in the course of a trip abroad this last summer I made a number of inquiries along this line to see if statistics had not been accumulated abroad with regard to the division or character of water consumption. In Germany in particular I found that records were available concerning the public uses of water, but there they virtually stopped. There was none of the division as between a domestic consumption and a manufacturing consumption which we are after, at least so far as I was able to find; and, of course, conditions of life and the use of water in this country are so different from the conditions abroad that we ought to study the problem at home. So your committee asks to be continued another year, Mr. Chairman, if that is the pleasure of the Association.

The President. I am sure we all are glad to hear that this important matter is going forward. I think no action is necessary to grant the continuance for another year, as asked for.

Next is the report of the Committee "to collect Information as to Low-Water Yields of Catchment Areas in New England, and, at their Discretion, Outside of New England," Mr. Frederic P. Stearns, chairman.

Mr. Harold A. Barrows. Mr. Chairman, the chairman of the committee has asked me to read this very brief progress report of the work of the committee, dated January 10, 1912.

Mr. Willard Kent, *Secretary*,
New England Water Works Association,
715 Tremont Temple, Boston, Mass.

Dear Sir, — The Committee on Yield of Drainage Areas has no extended report to make at this time, but can report substantial progress in accordance with the plan described briefly in the report of the committee made to you at the annual convention in September. Circular letters and blank forms were submitted to all the members of the committee on October 25, with the ex-

pectation of including information upon the yield of drainage areas through the year 1911, which, owing to the conditions of drought prevailing well into the season, it was necessary to include in the period covered by our investigations.

Preparation of data by members of the committee and other parties is well under way, but a further period of several months will be required in which to complete this work.

Very truly yours,
FREDERIC P. STEARNS, *Chairman,*
H. K. BARROWS, *Secretary,*
For the Committee.

THE PRESIDENT. I think the work of this committee is one of the most important matters that the Association has in hand at this time, and while we want the result as promptly as possible, I think the necessary time to put the information in the best shape should be granted.

MR. J. WALDO SMITH then spoke of matters connected with the crossing of the Hudson River, giving incidents and figures concerning the investigation and progress of the work.

THE PRESIDENT. Is the Committee to Prepare a Standard Specification for Fire Hydrants now ready to report?

REPORT OF COMMITTEE TO PREPARE A STANDARD SPECIFICATION FOR FIRE HYDRANTS.

MR. GEORGE A. STACY. Mr. President, we have heard from Mr. Lacount. He has sent a preliminary statement to accompany the report made by the full committee, with a request that it be read. Mr. Sullivan, a member of the committee, will now read the statement, which is in the nature of an historical sketch introductory to the printed report which is before you.

MR. WILLIAM F. SULLIVAN. I regret Mr. Chairman, that Mr. Lacount is not here to-day, because of illness, to make this statement, but it has just been handed to me to read. It is as follows:

"Two years ago this committee made a progress report and submitted a tentative set of specifications for post hydrants. A year later we reported that unexpectedly we had been unable to carry out certain tests as planned on

present makes of hydrants, due to the fact that the manufacturers were unwilling to assist the committee by loaning sample hydrants for test, and it was recommended that the specifications previously reported be continued as the tentative specifications of the Association.

"Although we have not yet received any assistance from the manufacturers, we nevertheless have been able to obtain during the past year several hydrants for test, and from these tests, which have cost several hundred dollars to carry out, we have obtained some of the information desired. As a result of the further study of the subject, a few amendments of the specifications previously submitted have been found advisable, and we now present for your final consideration and adoption the specifications as amended, advance copies of which were sent to the members of the Association with the notice of this meeting. A copy of the specifications and notice of the meeting were also sent to each hydrant manufacturer of whom we had any knowledge.

"We wish to say also that these specifications have been sent to the hydrant committee of the N. F. P. A., and also American Water Works Association, and from the replies thus far received from the N. F. P. A. Committee and from previous interviews with chairman of the American Water Works Committee, it is believed that the specifications will meet the approval of both committees.

"We therefore trust that this Association will approve the specifications substantially as now submitted, to the end that there may be finally one standard hydrant specification for this country.

"H. O. LACOUNT, *Chairman.*"

PROPOSED SPECIFICATIONS FOR POST HYDRANTS.
FINAL REPORT OF THE COMMITTEE.

1. SIZE.

a. The size of hydrants shall be designated by the nominal diameter of the net valve opening, which must be at least 5 inches for hydrants having two $2\frac{1}{2}$-inch hose connections and 6 inches for those having three or four $2\frac{1}{2}$-inch hose connections.

In hydrants having valve openings of shapes other than circular, the designation of size must be the diameter of the circle equal in area to that of the valve opening.

b. The net area of the waterway at the smallest part when the hydrant is wide open must not be less than that of the valve opening.

In new designs it is recommended that inside diameter of hy-

drants, especially at the outlets, be 7 inches and 8 inches respectively for hydrants having 5-inch and 6-inch valve openings.

c. Hydrants must be fitted with bell ends to fit New England Water Works Association standard pipe, or with flanges of standard dimensions and having standard bolt layouts, published jointly by the American Society of Mechanical Engineers and the National Association of Master Steam and Hot Water Fitters, as given in the following table. Holes are not to be drilled on the center line, but symmetrically each side of it.

Size of Pipe. Inches.	Diameter of Flange. Inches.	Diameter of Bolt Circle. Inches.	Number of Bolts.	Size of Bolts. Inches.	Flange Thickness at Edge. Inches.
2	6	$4\frac{3}{4}$	4	$\frac{5}{8}$ x 2	$\frac{5}{8}$
$2\frac{1}{2}$	7	$5\frac{1}{2}$	4	$\frac{5}{8}$ x $2\frac{1}{4}$	$\frac{11}{16}$
3	$7\frac{1}{2}$	6	4	$\frac{5}{8}$ x $2\frac{1}{2}$	$\frac{3}{4}$
$3\frac{1}{2}$	$8\frac{1}{2}$	7	4	$\frac{5}{8}$ x $2\frac{1}{2}$	$\frac{13}{16}$
4	9	$7\frac{1}{2}$	4	$\frac{3}{4}$ x $2\frac{3}{4}$	$\frac{15}{16}$
5	10	$8\frac{1}{2}$	8	$\frac{3}{4}$ x 3	$\frac{15}{16}$
6	11	$9\frac{1}{2}$	8	$\frac{3}{4}$ x 3	1
7	$12\frac{1}{2}$	$10\frac{3}{4}$	8	$\frac{3}{4}$ x $3\frac{1}{4}$	$1\frac{1}{16}$
8	$13\frac{1}{2}$	$11\frac{3}{4}$	8	$\frac{3}{4}$ x $3\frac{1}{2}$	$1\frac{1}{8}$
10	16	$14\frac{1}{4}$	12	$\frac{7}{8}$ x $3\frac{5}{8}$	$1\frac{3}{16}$
12	19	17	12	$\frac{7}{8}$ x $3\frac{3}{4}$	$1\frac{1}{4}$
14	21	$18\frac{3}{4}$	12	1 x $4\frac{1}{4}$	$1\frac{3}{8}$

Where working pressure is from 125 to 250 pounds, the standard for heavy flanges must be used.

2. GENERAL DESIGN.

a. Any changes in diameter of the water passage through the hydrant must have easy curves and all outlets must have rounded corners of good radius.

b. Hydrants must be so designed that with ordinary usage they will not cause water hammer.

c. Hydrants must be so designed that the leaded joint underground can be strapped.

In any new design it is recommended that the hydrant be so constructed that when the valve is shut it will remain tight when top of hydrant is removed or barrel is broken off.

3. MATERIAL OF BODY.

The hydrant body shall be made of cast iron of good quality, such as shall make the metal strong, tough, and of even grain. The strength of the cast iron must be that required by the specifications for standard cast-iron pipe 12 inches and less in diameter.

4. HOSE NIPPLES AND VALVES.

a. Hose nipples must be of bronze, threaded with a fine thread into the hydrant, and securely pinned in place.

b. Hose threads on all hydrants to be installed in any given community must of necessity be interchangeable with those already in service, but, where practicable, threads should conform to the 1906 National Standard adopted by the National Fire Protection Association. The essential features of the "National Standard" are a 60 degree V-thread, outside diameter on male threads of $3\frac{1}{16}$ inches and $7\frac{1}{2}$ threads per inch.

c. Inside hose-gate valves must have bronze working parts and be of rugged design and must not introduce an unnecessary friction loss. There must be ample clearance between the gate and the hydrant body when the gate is in any position. The gate and parts should be interchangeable and the valves should be located so as to be as accessible as possible for repairs. The gate must be designed so that it cannot come off in use. The top of the stem must be below the level of the hydrant stem nut so that the hydrant wrench can be freely operated. If outside hose-gate valves are used instead of inside valves, they must be of bronze or of iron with bronze trimmings, with lugs cast on the valve body, each valve must be bolted to the hydrant by two $\frac{3}{4}$-inch tap bolts, spaced $5\frac{5}{8}$ inches on centers. The valves must not project further than necessary and must be of the inside screw type, placed in a vertical position with the hand-wheel at least 3 inches below the base of the operating nut.

d. The stems of the hose valves must be not less than $\frac{3}{4}$ of an inch in diameter for the $2\frac{1}{2}$-inch valves, and not less than $\frac{7}{8}$ of an inch in diameter for the valves at the steamer connections.

e. The stem nut of the inside hose-gate valve must be $\frac{1}{2}$ of an inch square.

5. HYDRANT VALVE.

a. The seat must be made of bronze, securely fastened in place.

b. The valve must be faced with a yielding material such as rubber or leather except that if of the gate type a bronze ring may be used. The valve must be designed so that it can be easily removed for repairs without digging up the hydrant.

c. With gate type of valve, clearance of parts must be such that corrosion will not make the parts inoperative.

6. DRIP VALVE.

a. A positively operating non-corrodible drip valve must be provided and arranged so as to drain the hydrant when the main valve is shut.

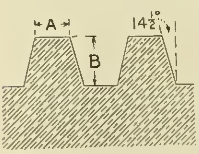
b. The seat of the drip valve must be securely fastened in the hydrant. All other parts of the drip mechanism must be designed to be easily removed without digging up the hydrant.

7. OPERATING STEM.

a. The operating stem at the base of the thread where threaded, and also where it passes through the stuffing box and gland, must be of bronze not less than $1\frac{1}{4}$ inches in diameter. The bronze must have a tensile strength of not less than 32 000 pounds per square inch. The remainder of the stem may be of iron with cross-sectional area not less than $1\frac{1}{2}$ square inches, except at couplings, where the area may be 1 square inch. The operating stem must be attached so that in operation it will be impossible for it to become detached.

b. The stem must terminate at the top in a nut of pentagonal shape, finished with slight taper to $1\frac{1}{2}$ inches from point to flat, except for hydrants to be installed where existing hydrants have different shape or size of nut, in which case the additional hydrant must have the same operating nut as the old ones for uniformity. The nut socket in the wrench must be made without taper so as to be reversible.

c. The thread which operates the valve must be Acme standard. See sketch opposite.



$$A = \frac{0.3707}{\text{No of threads per inch}}$$

$$B = \frac{1}{\text{Twice No. of thds per inch}} + .01''$$

8. STUFFING BOX AND GLAND.

a. The stuffing box and gland must be of bronze or bronze-bushed. If a packing nut is used, it must be of bronze. The bottom of the box and end of the gland or packing nut must be slightly beveled.

b. Gland bolts or studs must be of bronze, iron, or steel, at least $\frac{5}{8}$ of an inch in diameter. The nuts must always be of bronze.

9. HYDRANT TOP.

a. The hydrant top must be designed so as to make the hydrant as weatherproof as possible and thus overcome the danger of freezing the stem. Provision must be made for oiling both for lubrication and to prevent corrosion. A reasonably tight fit should be made around stems.

b. There must be cast on the hydrant top, in characters raised $\frac{1}{8}$ of an inch, an arrow at least 4 inches long showing direction to open, and the word " Open " in letters 1 inch high.

10. HOSE CAPS.

a. Hose caps must be provided for all hose outlets, and must be securely chained to the barrel with a welded chain of wire not less than $\frac{1}{8}$ of an inch in diameter.

b. The hose-cap nut must be of the same size and shape as the stem nut.

c. A leather washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed.

11. MARKINGS.

Hydrants must be marked with the name or trade mark of the manufacturer, the nominal size, and the year of manufacture. All letters and figures must be cast on the hydrant well above the ground line. They must be 1 inch high and raised $\frac{1}{8}$ of an inch on the casting.

12. TESTING.

a. Hydrants must be tested to at least 300 pounds per square inch before leaving the factory. If the working pressure is over

150 pounds per square inch, the hydrants must be tested to twice the working pressure. The test should be made with the valve open in order to test the whole barrel for porosity and strength of hydrant body. A second test should be made with the valve shut in order to test the strength and tightness of the valve.

b. Hydrants must be fully opened and closed before shipping in order to test the freedom and strength of the parts. The conditions of the test should be made as severe as are liable to occur in service when using a hydrant wrench at least 17 inches long.

13. DIRECTION TO OPEN.

Hydrants must open to the left (counter-clockwise), except those to be installed where existing hydrants open to the right, in which case the additional hydrants must turn the same as the old ones for the sake of uniformity.

H. O. LACOUNT, *Chairman*,
GEORGE A. STACY,
FRANK A. McINNES,
FRED W. GOW,
WILLIAM F. SULLIVAN,
Committee.

THE PRESIDENT. Gentlemen, you have heard this report. Before taking action on this important matter I think full discussion of it should be had, and I think it only proper to say that the associate members having to do with hydrants are entitled to take part in the discussion. The matter is now before you, gentlemen.

MR. SAMUEL A. AGNEW. Mr. President, considering the fact that I have talked with some of the hydrant manufacturers and they have expressed a desire to be called in conference with this committee, before it was decided just what should be done with regard to changing hydrants and adopting a standard specification, I am rather surprised to hear that they have given no assistance whatever.

I do not know that it is in order, but if it is I would suggest that a committee be appointed to confer with the manufacturers, so

that the whole question may be threshed out with the men who certainly ought to know something about making hydrants.

As I understand, there are a good many minor changes suggested in this report, which would result in a considerable difference between the hydrants which are suggested and those that we are using at present. This will necessitate on the part of the water departments the keeping of duplicate sets of parts of different kinds of hydrants, which I should consider very undesirable. It is hard enough to take care of the hydrants we have and to keep on hand sufficient parts to keep the present hydrants in repair, without having to have a new set of hydrants and parts for them.

Mr. Sullivan. Mr. President, I would say that this committee has already conferred with the manufacturers. We had one conference in Boston, and at that meeting the manufacturers said that they would continue to interest themselves in this matter, and that they would keep in touch with this committee. I do not know the reason why the manufacturers failed to coöperate and keep in touch with the hydrant committee. I know that Mr. Lacount, as the chairman of our committee, has given much time and thought to these specifications, and I know that on several occasions he gave the manufacturers an opportunity to come before the committee and discuss changes in the specifications.

As a member of the committee, I do not want to antagonize the manufacturers, and I think the committee as a whole is perfectly willing that the manufacturers even at this date should come in and confer with them. If another committee is appointed I do not see that there will be much need of the present one continuing along the lines upon which we have been working.

In order to bring the matter before the Association, which is the body to decide, and to bring it to your consideration so that you may act upon it, I move the adoption of these specifications as printed. I do not make this motion with the idea of rushing it through, but simply to give the members and the hydrant manufacturers who are here to-day in large numbers, an opportunity to express themselves and make known their objections.

I know the members of the committee are willing to meet the hydrant manufacturers on almost any ground. The committee's work has been simply to prepare a definite set of specifications,

so that the members of this Association, or any purchasers of hydrants, may know exactly what is a 5-in. hydrant or a 6-in. hydrant and the hydrant's characteristics and efficiency, its strength, durability, and method of manufacture on lines similar to the New England Water Works Standard Specifications for Cast-Iron Pipe. I hope that the members and the hydrant manufacturers here to-day will express themselves, so that by this means, at least, the hydrant committee will be able to get some information and learn what the manufacturers and members want regarding these specifications. The final word, however, with regard to hydrant specifications must come from the Association. You, gentlemen, are the final judges, for you buy and pay for the hydrants.

Mr. Frank C. Kimball. I second the motion that we adopt the specifications.

The President. The matter is still open for discussion. I see several representatives of the manufacturers present, if I am not mistaken. Have they anything to say upon the subject? Are they satisfied with the specification, and if not, what changes do they desire?

Mr. Charles R. Wood. Mr. President, I have been asked by some of the manufacturers to speak for them on this subject. I will say that while we had some conferences with the committee we never had any particular standing as a body in any way. The manufacturers with whom I have discussed the matter seem to think that if the Association would appoint a committee, say, of five manufacturers who were interested in the manufacture of hydrants and associate members of the Association, to meet with Mr. Lacount, Mr. Sullivan, Mr. Stacy, and Mr. McInness, we might cut down the small differences which exist in the specifications as they are presented here to-day. These suggested specifications — I notice they are marked "Subject to revision" — differ greatly from the last set that were published, and, of course, the manufacturers have not had a chance — I think Mr. Sullivan will bear me out in this — to take up with the committee the changes which have been made. The manufacturers would like very much to have a committee appointed from the associate members who are interested in making hydrants, so they would have at

least some standing, perhaps with the addition of some officer of the Association, the President or some one, to make a little more formal matter of it, to take this matter up with your committee.

On the question of submitting hydrants for test, a number of us did agree to submit hydrants for test, and a number of us had them ready to send, with the idea that the test was for the purpose of showing the flow of water for the various sizes of valve openings. When we asked, however, what tests were going to be made, we were told that they would do whatever they wanted with the hydrants. I do not know whether that report came from the full committee, or whether it was a report to us individually, or whether every manufacturer was told the same thing; but we were told that our hydrants would be tested in any way the committee liked, whereas the original idea the manufacturers had was that they would be tested for the flow of water through the body of the hydrant.

We would be very glad to have representatives of the manufacturers, say five, the same number as the present committee of the Association, or whatever number you may think proper, take the matter up in detail, because there are but a very few things with which the manufacturers are not entirely satisfied in the specifications as they read to-day.

THE PRESIDENT. Is there any other statement to be made by any of the manufacturers?

MR. WOOD. Mr. Chairman, I was asked to speak for most of the manufacturers present. It did not seem necessary for all of us to talk along the same lines, but there are a number of manufacturers here, if the Association wants to hear from them.

THE PRESIDENT. The matter seems to stand in this way: We have a specification which has been prepared by a most competent committee, which, I take it, meets for the most part the approval of the manufacturers, but the manufacturers want some changes made in it. I have no idea what the character of those changes may be, but it seems that it would be well, perhaps, to defer action until a conference could be had along those lines. What do you say, Mr. Sullivan?

MR. SULLIVAN. Mr. President, in regard to the revision of

these specifications from the previous draft, I would say that most of the revision was done from suggestions made by the manufacturers. Now, I presume that in the main these specifications are satisfactory to all parties; and I would offer a suggestion, although I have made a motion and it may not be in order at this time, that these specifications be gone over rapidly by sections or by items, so that we may find out what items do not accord with the ideas and practice of the hydrant manufacturers. Of course the Association has the authority to appoint an additional committee to meet with the present hydrant committee, and I do not think any member of the hydrant committee will object to that. It seems to me, however, as this thing has been hanging fire for several years, we might be able to clear it up more quickly by having the hydrant manufacturers who are here express their views now. I earnestly suggest that this matter be taken up, and that the hydrant manufacturers point out what items or what sections in the specifications they object to.

Mr. Wood. Mr. President, we have had these specifications in our hands only four or five days, and we have not had time yet to discuss the matter thoroughly among ourselves. We would like, rather than to go into detail as to requests for changes in the specifications at present, to have a chance to confer among ourselves, and then to confer with the committee. There may be some suggestions which it will not be necessary for us to make, when we know all the reasons which the committee have for suggesting certain paragraphs in the specifications.

The President. It seems to the Chair that there is no occasion for a change in the committee; that our present committee can handle this matter as well as any that can be appointed; and it seems to the Chair, further, that the manufacturers are well organized and well represented, and that they can present the matters that they have in mind to the committee, and that the committee can consider them and report back to the Association at a very early date. It would seem to the Chair that this would be the wisest solution of the problem. There is a motion before you, gentlemen, to the effect that these specifications be adopted. Is there any further discussion?

Mr. Frank L. Fuller. Mr. President, I would like to ask the

committee in regard to a point which, perhaps, is one of minor importance, but on page 80, in speaking of the operating stem, it says it shall be "finished with slight taper." Then, further on, it says: "The nut socket in the wrench must be made without taper so as to be reversible." I think the fire underwriters prescribe that the operating stem shall be without taper, and also that the nut on the wrench shall be without taper. It seems to me that if there is a taper on the stem there should be one in the wrench, and I would like to ask the committee what the object is in having the wrench without taper and the stem with taper.

Mr. George A. Stacy. A hydrant wrench is liable to be used either side up, and I do not see how you could have a taper in your wrench unless you had it marked and could be sure that the firemen were going to have it that side up all the time. The taper on the nut makes it a little easier to fit the wrench on, as a man rushes to a hydrant to open it, in the excitement of a fire. It is not correct mechanically, perhaps, but it is practically. If the hydrant nut fitted the wrench the whole way, it would be difficult to get the wrench on under the conditions that exist at a fire. Another factor which enters into the problem is the small boy with a stone for a hammer. If the wrench fits tight all the way down on the nut, it takes but a few minutes for a small boy to fix the nut so that you cannot get the wrench on, without some trouble. They do that sometimes in the best communities. Now, if you have got a little taper on the nut, and you have got a little leeway in putting your wrench on, a man will fit it more quickly, and you will get sufficient bearing on the base, where it will fit closely, so that you will have sufficient bearing to operate it without any trouble.

Mr. M. N. Baker. If it is in order, Mr. President, I would like to offer a substitute for the motion before the Association, to this effect: That the associate members interested in the manufacture of hydrants be requested to confer with this committee on the subject, and that the committee report to the Association at a later date.

It seems to me that will perhaps clear the ground. I offer it merely as a suggestion to aid in getting the matter straightened out.

The President. Mr. Sullivan's motion is for the immediate adoption of the specifications as they stand. Mr. Baker's substitute is to request the associate members to confer with the committee, and to request the committee to report again to the Association.

Mr. Sullivan. Mr. President, I am willing to withdraw my motion for the adoption of the specifications. I made the motion so as to get the specifications discussed. With the permission of the gentleman who seconded my motion, and if there is unanimous consent, I withdraw my motion for adoption.

We have with us to-day Mr. Teague, who is an assistant to Mr. Lacount, our chairman; he can give you some data regarding the hydrant tests. He is not a member of the Association, and I respectfully ask that the privileges of the floor be extended to him to speak regarding the hydrant tests while the members are here, so they can better know what the committee's ideas were in making these tests.

The President. Do you suggest that he speak to us before the disposition of the matter which is now pending, Mr. Sullivan?

Mr. Sullivan. I withdraw my motion.

Mr. Kimball. I will withdraw my second.

Mr. Waldo Smith. I thoroughly agree, Mr. President, that the consideration of this matter should be postponed. I know that there are a great many engineers and water-works superintendents here to-day who feel that there has not been sufficient time since this report has been out to consider it. The first of the year is a very busy time, and a great many of us have not had time to consider this report. I am in favor of Mr. Baker's motion, except I believe it would be wiser, instead of leaving it to the manufacturers to get together as a whole with this committee, to have the President of the Association appoint a committee of the manufacturers, not a large number, whose business it will be to learn the views of the rest of the manufacturers and confer with the committee. That is the only difference of opinion I have with Mr. Baker; but it seems to me that perhaps the matter can be handled better in that way than by leaving it to all the manufacturers.

The President. What do you say on that point, Mr. Wood?

Mr. Wood. That was the original suggestion that we made, that the President of the Association appoint a committee of five, because there were five on the other committee, and that would seem to be a sufficient number to make up the committee. That would be very satisfactory to the manufacturers. The number of the committee might be left to the discretion of the President.

The President. Of course under this arrangement those men would not be members of the committee. It would be their duty to present the manufacturers' side of the case to the committee.

Mr. Wood. Certainly.

Mr. Baker. I am perfectly agreeable to that, Mr. President, if that is the idea of the Association. It does not make any difference whatever to me how it is got at, as long as the end is achieved.

Mr. Stacy. Mr. President, I think I can say there is no objection on the part of the committee to this conference. From start to finish we have only been anxious to get the best there was to get, and we have felt that we needed all the knowledge that there was in the business. We certainly concede to the manufacturers that they know something about hydrants, and the conference we had was a valuable one, although we were considerably apart on some things. While this matter has been dragged along, I think it is the desire of the committee that when the work is completed it should stand on solid ground, and that, as far as it is possible for human minds to agree, we should all agree that these specifications are the best for all parties that can be drawn up with our present knowledge.

The President. I take it that the manufacturers will be prepared to act promptly on this, Mr. Wood?

Mr. Wood. At the call of the chairman of the committee.

Mr. M. S. Kahurl. Mr. President, I would like to ask a question. We are manufacturing hydrants, and how will those of us stand who are not appointed on the committee? Will we be entitled to the information that is to be given to and from the committee?

Mr. Wood. As far as the manufacturers are concerned, we shall be only too glad to get suggestions from any manufacturer

of any hydrant, and all the information that we would have would be given out, and presumably all the information which the committee received would be given out to any manufacturer who wanted to know about it.

THE PRESIDENT. It is the feeling of the Chair that the best results would be obtained by allowing every manufacturer to go to the committee with all the "kicks" he has to make, and allowing every member of the Association to go with his.

MR. BAKER. That was my idea in suggesting, as I did, that the associate members who were interested in the subject be asked to confer with the committee, so that they could all have a chance. If they want to organize a subcommittee to take up the active work, that is within their power.

THE PRESIDENT. The question, I believe, is on Mr. Baker's motion.

MR. M. F. COLLINS. Before that motion is put, Mr. President, Mr. Sullivan has suggested that there is a gentleman here who wants to give some statistics on hydrant tests. It will only take a few minutes, and I hope the gentleman will have a chance to tell the Association what he has to say with regard to that matter.

THE PRESIDENT. I was planning to give him the floor, Mr. Collins, directly after putting this motion.

(Mr. Baker's motion that the associate members interested in the manufacture of hydrants be requested to confer with the committee, and that the committee report to the Association at a later date, was adopted.)

W. O. TEAGUE, Esq. Mr. President, I think what I have to say will not be so much to the point now as it would have been previous to the adoption of the motion which has just been put.

I wanted to say a word about the purpose of the tests which were made. The first draft of the specifications that was gotten up met the approval generally of the manufacturers, except as regards the size of the valve opening in the hydrant. The committee, as you remember, specified a 5-in. opening, — in other words, an area corresponding to a 5-in. diameter circle, — for a two-way hydrant. The question was raised as to whether this was neces-

sary or not. In order to settle that, it was necessary to make tests. We endeavored to get hydrants for this purpose from the manufacturers, but were unable to do so. We then, as was stated by Mr. Lacount, got some representative hydrants, and made tests on them, with the result that we showed conclusively that for a two-outlet hydrant a 5-in. valve opening is advisable. It seemed to us that that settled the main objection which the manufacturers had to the specifications as written at that time.

In addition to the tests, we made slight revisions in the draft of the specifications, to cover as far as possible the points — or objections you might call them — raised by the various manufacturers, so as to cover their particular design of hydrant without necessitating changes. Of course that could not be carried to an extreme and have the specifications suit all the hydrants that are made to-day. The best that could be done was to have pretty general specifications, representing the best conservative practice of the day in hydrant construction. For that reason it seems to me that the specifications as now before you are in final form, and that there are no vital points which need further consideration.

As I understand it, the purpose of the hydrant committee was, first, to recommend a basis for the designation of the sizes of hydrants. This has been done. In addition, it was the purpose of the committee to prepare a standard for good design, good construction, good workmanship, durability of parts and serviceability of the hydrants. We feel that the specifications as now written cover all these points, and it does not seem that further discussion of the matter with the hydrant manufacturers is going to lead anywhere. It simply means a delay. This work has been carried on in conjunction with the work which the Factory Mutual Fire Insurance Companies are doing along a similar line in connection with mill yard fire hydrants, and in view of that the committee has had the benefit of all the knowledge and data which the Mutual Companies have on the subject.

The thought in outlining these specifications was to have the hydrant in the street the same, or as nearly as possible the same, as that in the mill yard. We found finally that the only real difference that was necessary was in regard to the independent gate. The hydrant in the street should, of course, have inside gates,

since the outside hose gates form an obstruction and are apt to be broken off, whereas for mill yard use the outside gates are preferable. That feature is covered in the specifications as presented here.

In connection with the tests which were made for friction loss in hydrants we had intended to include in the specification a reference to the results; and in order that this may be made a matter of record I would like to read an abstract from Mr. Lacount's letter to the members of the committee, or, rather, the committees of the several associations, — that is, the New England Water Works Association, the American Water Works Association, and the National Fire Protection Association.

"It is proposed that the following be inserted in Article 2 on page 78: '*b*. With the hydrant discharging 250 gallons per minute through each 2½-in. hose outlet, the total friction loss of the hydrant shall not exceed two pounds for two-way, three pounds for three-way, and four pounds for four-way hydrants.'"

This will of course advance the lettering of articles *b* and *c* to *c* and *d* respectively. As regards the maximum allowable friction losses specified in this item, we wish to say that these are considered very liberal, in view of the results that were obtained in the tests; that is, that with very little change in the average hydrant as made to day, such as rounding outlets and having good surfaces, the average hydrant could come well within this requirement. We did not think it advisable to endeavor to cut this allowable loss down too fine because we did not know where to stop. It is possible that later on these figures can be revised to some extent, but for the present, in order to get some working arrangement, it is proposed that friction losses as specified be allowed.

I have nothing further to say on the matter except that Mr. Lacount and myself are very confident that the work has been carried to such a point that no material improvement of the specifications can be expected from a further discussion or consideration of the details with the manufacturers, and for this reason we hoped that the specifications would be adopted as presented.

Mr. Leonard Metcalf. Mr. President, might I through you make one suggestion to the committee in regard to these specifications, which is suggested by a casual reading of them, and that is that they should be self-contained, so you will not have to refer to any other document to have your full specification. I notice that in paragraph 3 the second sentence reads: "The strength of the cast iron must be that required by the specifications for standard cast-iron pipe 12 in. and less in diameter." Wouldn't it be desirable to have this requirement embodied in these specifications, so that in reading the specifications you have the entire thing before you?

Mr. Sullivan. Mr. President, I remember that point was discussed at one of our meetings, and it was thought that embodying the New England Water Works Specifications for Standard Cast-Iron Pipe would make these specifications rather long; but I think the suggestion of Mr. Metcalf is good, and I do not know but it is the best thing to do.

Mr. Charles E. Chandler. Mr. President, may I make one suggestion, at the request of the chief of the Fire Department of Norwich, Conn.? Under "Hose Caps," paragraph *c*, it reads: "A leather washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed." Our chief, Mr. Stanton, is of the opinion, and I beg the privilege of suggesting here, simply for the consideration of the committee in their further work, that a babbitt-metal washer that will not dry up and fall out, as leather washers do, might be an improvement over the leather washer. He has had a sketch made according to this idea, which I would be glad to have any of the members, and especially the manufacturers, look at, and if they should find any great difficulties in relation to the matter, of course they would not need to consider it further. But if it should prove, as Mr. Stanton thinks, that the babbitt-metal washer would be more effective and no more expensive, the object of this suggestion would be accomplished.

Mr. Sullivan. Mr. President, that matter was taken up while we were having a conference with the hydrant manufacturers. I know it was discussed *pro* and *con* very thoroughly. The object of the leather washer was that when there were several

outlets to a hydrant, and only one line of hose attached, and no independent gate-valves, the water would be kept from spurting from the unused outlets and wetting the hydrant man who was operating the hydrant. But that is only a small detail, and I know the committee will be willing to consider it, although the leather washer was the outcome of the joint conference between the committee and the manufacturers.

Mr. A. E. Martin. With regard to the leather-washer business, a year ago in Springfield we changed all our hydrant screw threads so that there should be no washers at all. We now use them plain without a washer, and we have no trouble in keeping the water from running out of the nozzles. They never leak at all; they are made very tight and metal faced.

Mr. Chandler. May I ask if there is any corrosion of the metal and sticking of the cap at times?

Mr. Martin. We never have had a particle of trouble so far. Of course we have only been using them a year, but before I went to Springfield I used hydrants in the same way for eighteen years, and I never had any trouble with them.

The President. This is a most interesting and profitable discussion, and it is to be hoped that it may be continued when the specifications are reported back, and when certainly it is to be hoped they may be finally adopted and the business thus be standardized, as other branches of our work have been standardized.

President's Address.

Gentlemen of the New England Water Works Association:

The past year has been, in most respects, one of quiet work and with no unusual events. In membership, there has been but a slight gain, the new members elected only slightly exceeding in number those lost through various causes. Financially, the Association has held its own, and the treasury is believed to be in satisfactory condition. These matters are set forth in the reports of the Secretary, Treasurer, and Editor, — which you have ust heard, — and do not need to be now repeated.

The deaths of ten of our members have been reported since the last annual meeting, namely:

		Elected to Membership.
John T. Fanning,	Civil Engineer, Minneapolis,	1885
Amos A. Gould,	Water Commissioner, Leicester, Mass.,	1896
C. A. Hague,	Civil Engineer, New York City,	1904
L. E. Hawes,	Civil Engineer, Boston, Mass.,	1888
L. P. Kinnicutt,	Chemist, Worcester, Mass.,	1893
A. R. McCallum,	Superintendent Water Works, Whitman, Mass.,	1906
C. W. Paine,	Civil Engineer, Highland, Cal.,	1888
W. H. Sears,	Civil Engineer, Plymouth, Mass.,	1899
Wm. H. Thomas,	Superintendent Water Works, Hingham, Mass.,	1887
W. P. Whittemore,	Chief Engineer Water Department, Attleboro, Mass.,	1886

From a physical standpoint, the year has been an interesting one, as the third in a cycle of dry years. The first part of the year was particularly dry, and, following two dry years, the deficiency in rainfall brought about conditions that were serious in many water-supply systems, especially where the catchment areas were small for the reservoir capacities.

This dry period, which now fortunately seems to have passed, has been one of the most notable that has occurred in New England since accurate records have been available.

One of the most important events of the year was appointing a committee by the Association to collect data as to this and other dry periods, and to study the whole subject. This committee is not yet ready to report, but it is believed that information will be obtained which will serve for many years as a basis for estimating the capacity of water supplies in New England.

It is nearly thirty years since there has been a record-making drought, and in this interval the records of the Sudbury River and a few other streams in the years following 1880 have been used as a basis for nearly all such calculations.

There is some reason for believing that earlier in the nineteenth century there was a drier period than that of the eighties, but records are inadequate.

When this report is available, it may be appropriate for the Association to discuss the question as to how far a practical rating of water sources should be based upon the records of the driest

year on record. Dry years may be classified according to the frequency with which they recur. There is a degree of dryness that is reached on an average once in ten years, and another reached on an average once in thirty years, the latter represented approximately by the dry period of the early eighties, and again by the dry period of the last few years. Presumably, there will be still drier years, which may be referred to in a general way as occurring not oftener than once in a century.

On the other hand, a water-supply system is seldom drawn to its ultimate capacity, and in fact can be but seldom so drawn with safety, because the consumption is always fluctuating, and enough water must be on hand to cover fluctuations and reasonable increases in rate, and in order to do this there is ordinarily some surplus capacity.

It may be questioned if it is justifiable as a practical business proposition to rate supplies on the droughts that only occur once in a century, or even on those which occur only once in thirty years, and whether it would not be better to take some less extreme basis, which basis could be established by proper records, and the limitations of which should be frankly recognized by writing them into all descriptions, and into the headings of tables.

For a city to be out of water is serious business. To be a little short one year in thirty may not be an intolerable condition, and it may be better business to have this happen than to build a whole water-works system so large that its capacity may only be needed once in thirty years.

Let us say, for example, that we will take some shorter period as a basis, such as ten years, and calculate the amount of water which can be certainly supplied nine years out of ten, and on an average in the tenth year, and take our chance on being a little short once in twenty or thirty years, if it so happens that the full rated capacity would be then used if it were available.

Following out this idea and developing it somewhat, it might be stated that a certain water supply was good for so many gallons per day four years out of five, for so many nine years out of ten, and for so many twenty-nine years out of thirty. Each figure for capacity in this series would be somewhat smaller than the preceding one, and the ratios between them could be fixed with

a fair degree of accuracy. We should then have a better idea of what chances we were taking, and what rating it was wisest to adopt.

It is the custom for the President to speak to you at the annual meeting upon some serious matter. Last year, our President gave us a most interesting survey of the whole field of water-works business throughout the civilized world. To-day, I choose a narrower subject, namely, the management of water works. I shall refer particularly to water works under municipal ownership, and I wish to consider the matter along somewhat broad lines.

The ownership and operation of water works by cities is a kind of municipal trading. That is to say, it has nothing to do with government, but is, on the other hand, engaging in private business by a public body, which business might otherwise be performed by private parties.

A public enterprise of this kind is always something of an experiment. There are cases where notable success has been achieved. We all agree that our Post-Office Department is, on the whole, well managed and gives better service than could be anticipated from private ownership. In European countries, the telegraph is managed by Government, and the service is generally cheaper than it is with us; but on the other hand, there are rumors of deficits in the Government telegraph accounts, and, so far as they occur, the taxpayers are making up for the lower charges on the messages. It is claimed that the privately owned telephone system in America is more efficient than any publicly owned system in the world.

We have not yet taken up government ownership of railroads (except in the unusual case of the Panama Railroad), but much has been done in this direction in Germany and other European countries, and in other parts of the world, including Canada and Mexico. Some excellent results have been achieved, but I think that most of us hold to the belief that company management of railroads is more appropriate and, on the whole, more efficient than government ownership.

In Europe, gas works and electric-light plants are frequently owned by municipalities, and in a few cases American cities have taken up these lines of trading.

In the beginnings of the water-works business in America, private companies played a large part, and many important works are still owned by companies; but as time has gone on, more and more undertakings have passed into public ownership, until a great majority of water-works plants are now owned by municipalities. In general, the management of publicly owned water works has been good, and has produced results satisfactory to the water takers, and not burdensome to the taxpayers. No doubt mistakes are made in municipally owned works, and some of these would be avoided by company management, but I doubt if the losses growing out of them would exceed those to be reasonably expected with private ownership of corresponding works.

Taking it right through, the public ownership of water works has been the most successful line of municipal trading thus far undertaken by American cities.

One fundamental reason for this is that the water-works business is naturally profitable. The income is easily and certainly collected, and is regular from year to year. Water can generally be secured and furnished at so small a cost that rates may be at once remunerative to the system and not burdensome to the takers. It has thus been possible in American cities to collect all necessary money to conduct the business, and it has rarely been necessary to burden the taxpayers in supporting these undertakings. These conditions have made it easy to operate plants without incurring deficits and with general satisfaction to the citizens, and have perhaps lead to easy-going ways in some matters, where better business methods might have been adopted.

I propose to talk to you to-day about this general subject, and see if we cannot do something toward getting better methods adopted by the works with which we have to do. I know that some of you have already done a great deal in this direction, and methods of management have been introduced which are admirable, as relating to particular parts of some systems.

There was presented to us two years ago* an excellent paper on depreciation as applied to the water-works business. Discussion brought out the fact that must have been known to nearly all of us, that systematic calculation and allowance of deprecia-

*Journal N. E. W. W. A., Vol. 24, p. 305.

tion charges is rarely carried out in publicly owned works. It may be said, also, that privately owned water works have, as a rule, neglected to make systematic depreciation charges until during the last years, when the regulation of such corporations and decisions of the courts as to reasonableness of rates, have made them imperatively necessary. It is now recognized that in the financial management of a privately owned water plant, the annual depreciation must be carefully calculated and allowed each year, and there seems to be no reason why corresponding calculation and allowance should not be made for a plant that is owned by a municipality.

The reform in regard to depreciation charges is a most important one, but it is only one of a whole series that might be made with advantage.

Take the case of profits, or the return upon the invested capital, or, in the case of an old plant, on the fair value of the property. I think it is often true that the water-works management is satisfied if a balance is left in the hands of the treasurer at the end of the year, after operating expenses and the interest on the bonded debt have been paid, and perhaps some money put into extensions. But is this the whole question? Why should not a plant earn a fair return on its value, regardless of the amount of its indebtedness?

There are cases where the bonds originally issued to pay for water-works construction have been paid off, where additional construction has been paid for from earnings, and where the department is free from debt. There are other cases, fortunately less common, where bonds have not been paid off, where the works are depreciated, and where the plant is not worth the amount of the bonded indebtedness. Most plants lie between these extremes.

Let us consider for a moment the case of the plant that is out of debt. It is possible to operate the plant so as to pay its way, and to make water rates so low that they will cover only operating expenses and such other general expenses as have to be met, and water may be supplied at much less than cost.

Some people believe, no doubt, that this is the best way to manage the business, and that when works have once been paid for, the public may properly be given the benefit of this condition,

and supplied with water at whatever rates less than cost prove to be feasible.

I am disposed to take another view of the matter and to hold that no water-works system can be called really self-supporting that does not earn a reasonable return upon the whole value of the plant, regardless of its bonded indebtedness. Certainly, the rates that will suffice to make such return are as low as rates could be made if the business were now being taken up for the first time, and in case the rate of return or percentage on the capital is as low as is consistent with good municipal management, the rates reached under this condition may be taken as representing the real cost of the service.

If a city has, by good management, or in any way, acquired a property which is valuable, and is capable, at fair rates, of producing a net revenue representing a fair rate of return on its value, is it not the duty of the municipality to manage it as any other owner of a trading enterprise would do, to secure the fair return that naturally grows out of the business, and use that return for the benefit of the citizens in any way that is proper? This view largely prevails in American cities, although it is not frankly recognized. There are many cases where the water revenue is turned into the general funds and serves to diminish the amount of money raised by taxation. There are cases where bridges and other municipal structures having no relation whatever to water works have been built with water-works money.

What I suggest to you to-day is, that this matter of accounting, which in the past has been of a most haphazard character, should be reduced to a definite basis, and standardized in accordance with sound business principles, but without defining too closely the rates of return that are to be earned, which I think should properly be left to the good business judgment of those having to do with the matter from time to time.

Then there is the question of taxation and free water. Why should public trading be done on different principles from private trading? Why should a water works be exempt from taxation, and why should the water works furnish free water for hydrants, schoolhouses, churches, and all other public and quasi-public institutions? Probably the underlying idea in many cities has

been that the taxes that would otherwise be paid might be taken as an offset for the free water furnished to the city, and that the two things would balance each other, and that it would save bookkeeping to let matters go without calculation.

But this certainly is not a good business basis. Why should not the water-works plant be assessed taxes on its reasonable value, and why should not collection be made for all the water and services that are rendered?

The Interstate Commerce Commission has done away with dead-head transportation upon railroads. This action was a wise one, for the pass system had been atrociously abused. It meant a drain upon the railroads that could only mean higher fares for those who paid. But were the passes upon the railroads more abused than the free-water arrangement is abused in the case of municipally owned water works? If passes are abolished on the railroads, why should not dead-heads be abolished in the water business? Certainly, because a taker is another department of the city government, it is not sufficient reason why it should be supplied with free water.

On the railroads in the old days, it was, no doubt, true that those who had passes caused more trouble and expense than other travelers. So, I think, in your water departments, you will find that the dead-head takers are, in general, those who waste the most water, and that it costs the most to take care of. That which costs nothing is treated with but little respect. The school-houses that are furnished with free water will use gang closets or self-flushing closets to save a little money in plumbing, and the water will go pouring through them day and night, because the janitor has not sufficient interest to shut them off at night because it costs nothing.

Our water-works statistics relating to physical matters have been well standardized. Would it not be worth while to extend our form to include information as to the value of properties, the amount of depreciation allowed, taxes paid and free water furnished, the net earnings, and the per cent. which these are of the values? To find out the facts is the first step. The laws and ordinances that will provide for bettering the conditions may be logically expected to follow.

One reform that might naturally grow out of consideration of the business along these lines would be better and more uniform schedules of water rates. I do not believe that there is any other line of business that has such great and unreasonable variety in its schedule of charges as will be found in water works.

We have had committees on water rates, and a great deal has been done to straighten up and eliminate these eccentricities, but much remains to be done. The business cannot be considered to be in satisfactory shape in any given case until a serious effort has been made to find out what revenue is really required and to prepare a schedule of rates that will distribute that amount as fairly as it can be distributed, among all the different takers, keeping in mind reasonable limits of simplicity.

There are several different ways of approaching this subject that have merit. Following different ones in different cases results in rates that are not easily compared with each other. I suggest that it ought to be possible at this time to agree upon a general form of water rates that could be used in all cases, but with figures omitted, with the idea that they would be fixed in individual cases, to meet the requirements of the revenue to be produced, and the relative abundance or scarcity of water. Where water is relatively abundant, a larger part of the amount to be raised will naturally be placed upon the fixtures, and upon the privilege of having connection and having water available. Where water is relatively scarce, the amount to be raised will be proportioned in greater measure, or even altogether upon the quantity of water taken by the various consumers.

Such a uniform schedule might be similar in its general form to the schedules with which we are all familiar. Under fixture rates, there would be specified all the fixtures that would be charged for, and the method of rating them would be defined once for all, but leaving the amount of charge to be made for each item to be determined according to the requirements of particular cases. Under meter rates, the point would be settled whether the gallon or the cubic foot was to be the basis of the calculation, whether minimum rates were to be used, or whether, instead, a fixed charge should be made for the service, as recommended by our committee some years ago, with an additional charge for all

water used, and the question would be taken up as to whether the scale should slide, and if so, at what points, and those points would be fixed; but the rates for water, and for the minimum charges, or for service charges would be left to be fixed according to the requirements of each case.

Schedules made up in this way could be directly compared with each other, which is something that cannot be done with present schedules of water rates, except in rare cases, as all of us know who have had to do with the rates, when effort has been made to investigate them by judicial procedure.

I may mention another question in water-works management, that arises in the case of cities or towns lying close together, and supplied most conveniently from one system. Cases of this kind are always numerous, and are especially so in the more densely settled parts of the country, as in New England. There is the case of the suburbs of a larger town, and the case of several towns lying near together, where the most available source of supply is at some distance, and where a single system would best serve all. This is a phase of water-works business where municipal ownership, up to the present time, has been relatively weak. The company form of management has had a distinct advantage under these conditions, because it knew no city lines and could use one system, as far as it was physically advantageous to do so.

In Maine, water districts have been formed, the boundaries of which followed the limits of the territory that could be conviently supplied with one system of works, rather than political boundaries. This plan has also been used in other places in America, in Europe, and quite generally in Australia, and it has been, on the whole, one of the most successful means of dealing with this phase of the question.

The Metropolitan water district here in Boston is, perhaps, the most conspicuous case of a successful solution of this problem, but in this case the state took a hand, so that the works as they stand are quite as much a state affair as a municipal undertaking.

In other cases, especially in the case of suburbs, the works of a city have been extended in adjoining country, or water has been sold wholesale. In other words, the municipality has been given leave to extend its trading beyond its own boundaries. Arrange-

ments of this kind have been frequent, and are likely to be still more so, and in case one of the towns greatly predominates in size over the others, there is much to be said in favor of this arrangement. But there are many other cases where several municipalities have independent works, and are so situated that, physically, one system would better serve than several independent ones. The water problem may be the only one that draws these particular municipalities together, and coöperation between them in the line of economical development is often difficult or seemingly impossible. This is one of the most interesting problems to be solved in the question of municipal ownership.

Election of Officers.

The President. There remains only one item of business to complete the year's work, and that is the report of the tellers. Are the tellers ready to report?

Mr. Samuel A. Agnew. The tellers appointed to canvass ballots for the election of officers for the ensuing year submit the following report:

President.

George W. Batchelder	301

Vice-Presidents.

J. Waldo Smith	292
Frank A. McInness	302
Millard F. Hicks	298
John H. Cook	301
Morris Knowles	300
Robert S. Weston	301

Secretary.

Willard Kent	304

Treasurer.

Lewis M. Bancroft	304

Editor.

Richard K. Hale	303

Advertising Agent.

George A. King	306

Additional Members of Executive Committee

George A. Stacy	301
John J. Kirkpatrick	301
Randolph Bainbridge	299

Finance Committee.

Albert L. Sawyer	301
Fred D. Berry	299
John W. Morgan	301

The President thereupon declared the above-named gentlemen to have been elected officers of the Association for the ensuing year, and requested Mr. George A. King to escort the newly elected President to the chair. Addressing Mr. Batchelder, the retiring President said: I pass you, sir, the gavel, and congratulate you upon your election, wishing you and the Association all success during the year which begins with this act. [*Applause.*]

The President. *Mr. Hazen and Gentlemen of the New England Water Works Association,* — I esteem it a great honor to have been elected as your President, and I shall make it my earnest effort during the coming year to advance your interests in every possible way in which I can. The success of any association depends very largely upon the coöperation in action of its members and its officers, and I sincerely trust that we shall all act together this year. I expect to receive the support and assistance of the other officers, of the committees, and of all the members, so that 1912 may be made a year of progress for the New England Water Works Association. I thank you, gentlemen. [*Applause.*]

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, Mass., February 14, 1912.

George W. Batchelder, President, in the chair.

The following-named members and guests were present:

Honorary.

Frederic P. Stearns.

Members.

A. S. Agnew, C. H. Baldwin, G. W. Batchelder, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, I. W. Brooks, G. A. Carpenter, George Cassell, J. C. Chase, R. D. Chase, M. F. Collins, A. W. Cuddeback, A. O. Doane, E. D. Eldridge, G. F. Evans, C. R. Felton, F. F. Forbes, F. L. Fuller, F. J. Gifford, A. S. Glover, Clarence Goldsmith, J. M. Goodell, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, T. G. Hazard, Jr., H. G. Holden, J. L. Hyde, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, J. H. McManus, N. A. McMillen, W. E. Maybury, John Mayo, H. A. Miller, F. L. Northrop, T. A. Peirce, Dwight Porter, P. R. Sanders, A. L. Sawyer, G. H. Snell, G. A. Stacy, T. V. Sullivan, W. F. Sullivan, H. L. Thomas, R. J. Thomas, L. D. Thorpe, J. L. Tighe, J. A. Tilden, E. J. Titcomb, C. H. Tuttle, W. H. Vaughn, L. J. Wilber, F. I. Winslow, G. E. Winslow, I. S. Wood. — 62.

Associates.

Anderson Coupling Company, by W. D. Cashin; Builders Iron Foundry, by F. N. Connet and C. J. Young; Chapman Valve Manufacturing Company, by J. T. Mulgrem; *Engineering Record*, by I. S. Holbrook; Darling Pump Manufacturing Company, by H. H. Davis; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by A. S. Glover, J. A. Tilden, and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey and R. D. Wertz; Norwood Engineering Company, by C. E. Childs; Pittsburg Meter Company, by B. A. Lester; Platt Iron Works Company, by F. H. Hayes; Rensselaer Valve Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop and D. F. O'Brien; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle, Jr., and E. S. Scott; R. D. Wood & Co., by C. R. Wood and H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 30.

GUESTS.

John N. Brooks, Torrington, Conn.; J. J. Prindiville, water commissioner, Framingham, Mass.; Frank S. Hamlin, water commissioner, Haverhill, Mass.; A. E. Barrett, water commissioner, Lowell, Mass.; Daniel H. Gorman, commissioner, East Greenwich, R. I.; Henry F. Wilkins, John P. Goodwin, water commissioners, Marblehead, Mass.; Arthur W. Beckford, Henry Newhall, Danvers, Mass.; C. L. Leary, engineer public works, Peabody, Mass.; John J. Nugent, commissioner, Beverly, Mass.; Harry Greenhalgh, president Water Board, Fall River, Mass.; A. Allen, water commissioner, Westfield, Mass.; Raymond C. Allen, Manchester, Mass.; W. H. McGinty, Frank S. Bailey, and Tenny Morse, Boston, Mass.; Prof. H. C. Ives, Worcester, Mass.; and E. F. Hughes, water commissioner, Watertown, Mass. — 19.

The Secretary read the records of the last meeting. On motion of Mr. M. F. Collins the records as read were adopted.

The Secretary presented applications for membership, duly recommended and endorsed, from Henry Newhall, Danvers, Mass., superintendent; J. J. Prindiville, South Framingham, Mass., member and secretary Framingham Water Commissioners; Charles A. Leary, Peabody, Mass., in charge of Water, Street, and Sewer Division, Public Works; Charles William Saxe, Newport, R. I., chemist in charge of Filtration Plant, Newport Water Works; Earl W. Kelly, Duluth, Minn., engineer for Duluth Water and Light Department; Myron L. Fuller, Brockton, Mass., formerly chief of Eastern Section, Division of Hydrology, U. S. Geological Survey, and now consulting engineer on underground water supplies; L. E. Thayer, Waterville, Me., trustee Kennebec Water District and city treasurer; Samuel R. Hatch, Duluth, Minn., assistant to manager, Water and Light Department, Duluth; Marvin C. Birnie, Springfield, Mass., who has been engaged with the Thompsonville Water Company, Spafford Springs Aqueduct Company, and Stanton Aqueduct Company; Howard C. Ives, Worcester, Mass., assistant professor of railroad engineering, Worcester Polytechnic Institute. — 10.

On motion of Mr. T. A. Peirce, the Secretary was directed to cast one ballot in favor of the admission of the applicants, and he having done so they were declared duly elected members of the Association.

THE PRESIDENT. The members of the New England Water Works Association, I take it, are always glad to welcome anybody

who is entering their business. We have such a man with us to-day, the Commissioner of Water and Fire Protection, Lowell, Mass., and it gives me pleasure to introduce Mr. A. E. Barrett, who will speak to you.

Mr. Barrett then spoke briefly in regard to the duties of his position.

The first paper of the afternoon was by Frederick N. Connett, mechanical engineer, Providence, R. I., on "Some Recent Applications of the Venturi Meter." The paper was illustrated by stereopticon views. The discussion of the paper was opened by Mr. Allen W. Cuddeback, who read a letter from Mr. John H. Cook, hydraulic engineer of the East Jersey Water Company. Mr. Richard A. Hale spoke of the successful work of the Venturi meter at Lawrence, and Mr. Connett replied to questions asked by Prof. Dwight Porter and Mr. Frank L. Fuller.

Mr. Richard K. Hale. Mr. President, it has come to my attention that several people have commented upon certain features of our Standard Specifications for Cast-Iron Pipe, and suggested revision. It has been suggested, therefore, that the matter be referred to the Committee on Cast-Iron Pipe, to determine whether these specifications should be revised or not. I therefore make the following motion: That the question of the desirability of revising the Standard Specifications for Cast-Iron Pipe be referred to the Committee on Pipe Specifications, with the request that they report on this matter at the next meeting of the Association.

The President. You have heard Mr. Hale's motion; is there anything to be said?

Mr. Dexter Brackett. As a member of that committee, I would like to ask if it is contemplated to refer the matter back to the original committee. I supposed that that committee had long ago gone out of existence.

Mr. Hale. I am informed that this committee is still in existence and that you are the chairman, and that Mr. McInnes and Mr. Forbes are the other two members.

Mr. Brackett. I wish to state that while I think it is desirable that the question of the Standard Specifications be considered, with a view of possibly adopting some changes which the experi-

ence of the last ten years has shown advisable, I should not be willing to retain the chairmanship of that committee, and really I should prefer not to be a member of it. I am, however, willing to give the benefit of any experience I may have had in the previous study of the question. I should think it would be well to have a committee of five, as I know there is much work to be done, and that the committee be appointed by the President. As to that committee making any report at the next meeting if that would mean anything in the shape of suggesting changes, I think there would be hardly time for that. I only offer this as a suggestion.

THE PRESIDENT. Mr. Brackett, the idea is simply that the committee will report on the advisability of making changes, — not to suggest the changes, but, if they deem it advisable and proper to have changes made, to report back to the Association at the next meeting so that we may act upon the matter then, and decide whether to appoint a new committee or to continue the old committee.

MR. BRACKETT. If that is the idea, I am satisfied.

(Mr. Hale's motion was adopted.)

THE PRESIDENT. The Executive Committee have been looking about for a place to hold the next annual convention. We sent out notices to the members, as you know, asking them to express their preferences. We have had 171 replies, and a summary of those replies is as follows:

First choice: Washington, 72; New York, 62; Philadelphia, 36. Scattering, 1.

Second choice: Washington, 26; Philadelphia, 71; New York, 37. Scattering, 2.

The committee have not yet decided upon the place, but they will probably be somewhat guided by the replies received from the members.

Mr. William S. Johnson, sanitary and hydraulic engineer, Boston, Mass., read a paper entitled "Some Things Domestic Meters do Not Accomplish." This paper was also illustrated by the stereopticon. It was discussed by Mr. Dexter Brackett, Mr. Allen W. Cuddeback, Mr. Frank L. Fuller, and Mr. George A. Carpenter.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Wednesday, December 13, 1911.

Present: President Allen Hazen, and members Morris Knowles, Lewis M. Bancroft, Richard K. Hale, Robert J. Thomas, and Willard Kent.

Five applications for membership were received and recommended for admission, namely:

For membership: John L. Hyde, city engineer, Westfield, Mass.; Walter E. Miller, C. E., Railroad Commission of Wisconsin, Madison, Wis.; Charles H. Ross, superintendent Waterloo Water Company, Waterloo, N. Y.; Alfred A. Young, superintendent Jewett City Water Company, Jewett City, Conn.

For associate: Eddy Valve Company, manufacturers of valves and hydrants, Waterford, N. Y.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, January 10, 1912, at 11.30 A.M.

Present: President Allen Hazen, and members J. Waldo Smith, Michael F. Collins, Leonard Metcalf, Irving S. Wood, Frank A. McInnes, Morris Knowles, Lewis M. Bancroft, Richard K. Hale, and Willard Kent.

Six applications for membership were received and recommended for admission, namely:

Sam H. Pitcher, assistant engineer, Worcester, Mass.; Hervey A. Hanscom, contracting engineer, Boston, Mass.; Lewis L. Wadsworth, president Hanscom Construction Company, Boston, Mass.; Herbert F. Salmonde, chemist West Parish Filters, Springfield Water Works, Westfield, Mass.; Paul Hansen,

engineer Illinois State Water Survey, University of Illinois, Urbana, Ill.; Harrington P. Stearns, assistant engineer Queens County Water Company, Far Rockaway, N. Y.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, at 2.30 P.M., Friday, January 26, 1912, pursuant to call of President.

Present: President George W. Batchelder, and members Frank A. McInnes, Randolph Bainbridge, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Voted: On motion of Mr. King, seconded by Mr. Bancroft, that the Secretary be instructed to send with the notices of the February meeting a request for the members to express their preference of a place for holding the next annual convention.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at the rooms of the Association, Tremont Temple, Boston, Mass., February 14, 1912, at 11.30 A.M.

Present: President George W. Batchelder, and members Frank A. McInnes, George A. Stacy, Richard K. Hale, George A. King, and Willard Kent.

The Treasurer's bond for $5 000, by the Massachusetts Bonding and Insurance Company, was presented and by unanimous vote approved.

Ten applications for membership were received and recommended for admission, namely:

For members: Henry Newhall, superintendent water works, Danvers, Mass.; J. J. Prindiville, water commissioner, Framingham Mass.; Charles A. Leary, engineer, Commission of Public Works, Peabody, Mass.; Charles W. Saxe, chemist in charge Filtration Plant, Newport, R. I.; Earl W. Kelly, engineer Water

and Light Department, Duluth, Minn.; Myron L. Fuller, consulting engineer, Boston, Mass.; L. E. Thayer, trustee Kennebec Water District, Waterville, Me.; Samuel R. Hatch, assistant to manager, Water and Light Department, Duluth, Minn.; Marvin C. Birnie, civil engineer, Springfield, Mass.; Howard C. Ives, professor water supply and railroad engineering, Worcester Polytechnic Institute, Worcester, Mass.

The result of ballot by members on place of holding next annual convention was presented as follows:

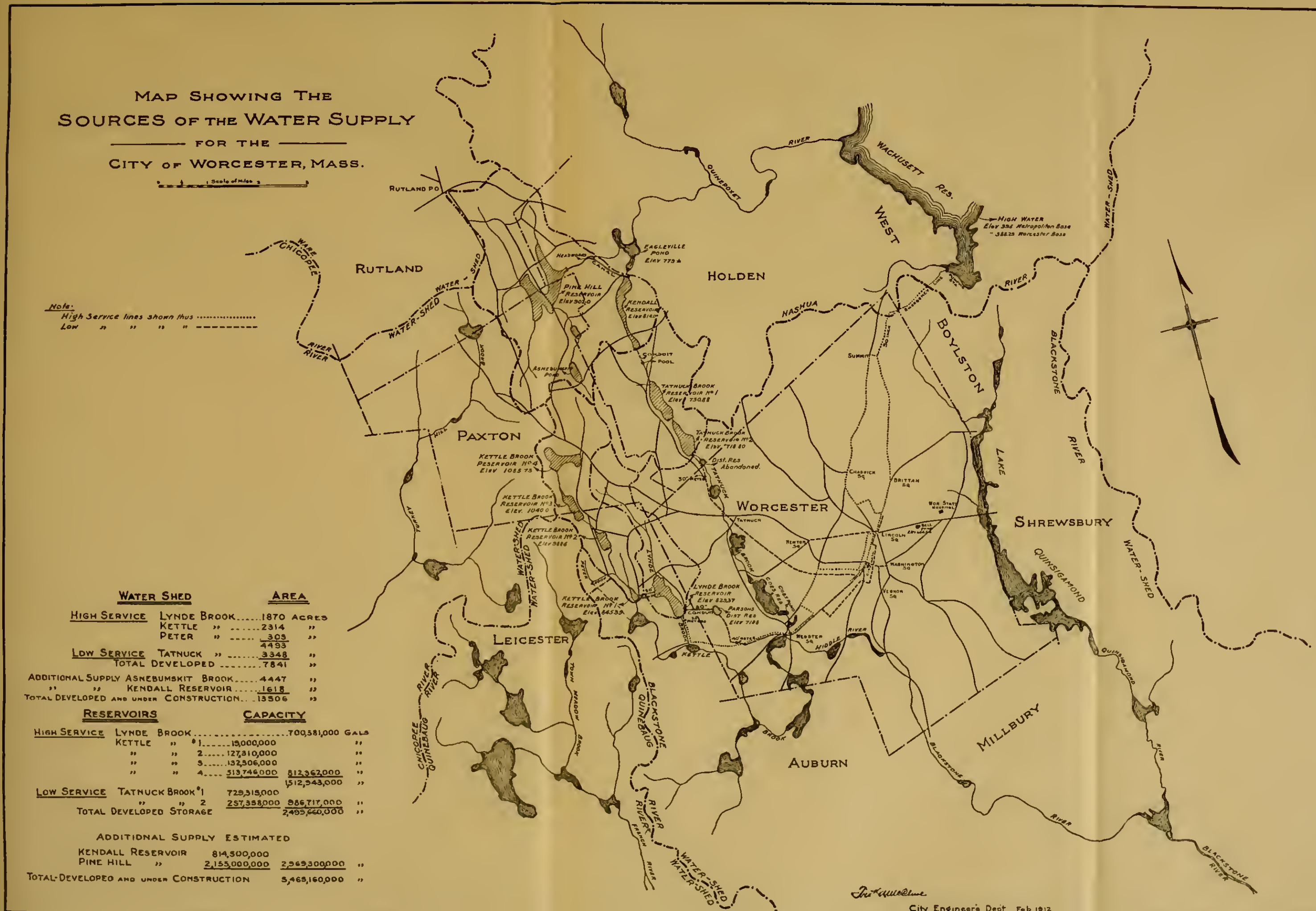
Replies were received from 171 members.

	First Choice.	Second Choice.
Washington	72	26
Philadelphia	36	71
New York	62	37
Boston	1	1
Providence	..	1

After a discussion, the matter was referred to a later meeting of the Executive Committee.

Adjourned.

WILLARD KENT, *Secretary.*


MAP SHOWING THE
SOURCES OF THE WATER SUPPLY
FOR THE
CITY OF WORCESTER, MASS.
Scale of Miles
Note:
High Service lines shown thus ....
Low " " " " ----------
WATER SHED AREA
HIGH SERVICE LYNDE BROOK......1870 ACRES
KETTLE " ....2314 "
PETER " ...... 303 "
4493
LOW SERVICE TATNUCK " ....3348 "
TOTAL DEVELOPED ....7841 "
ADDITIONAL SUPPLY ASNEBUMSKIT BROOK.....4447 "
" " KENDALL RESERVOIR......1618 "
TOTAL DEVELOPED AND UNDER CONSTRUCTION...13506 "
RESERVOIRS CAPACITY
HIGH SERVICE LYNDE BROOK..................700,581,000 GALS
KETTLE " #1......19,000,000 "
" " 2.....127,310,000 "
" " 3.....132,306,000 "
" " 4.....513,746,000 812,362,000 "
1,512,943,000 "
LOW SERVICE TATNUCK BROOK #1 729,319,000
" " 2 257,398,000 986,717,000 "
TOTAL DEVELOPED STORAGE 2,499,660,000 "
ADDITIONAL SUPPLY ESTIMATED
KENDALL RESERVOIR 814,300,000
PINE HILL " 2,155,000,000 2,969,300,000 "
TOTAL-DEVELOPED AND UNDER CONSTRUCTION 5,468,160,000 "
RUTLAND
RUTLAND P.O.
HOLDEN
PAXTON
WORCESTER
LEICESTER
AUBURN
MILLBURY
SHREWSBURY
BOYLSTON
WEST
WACHUSETT RES.
HIGH WATER
QUINEPOXET
RIVER
NASHUA
EAGLEVILLE POND
PINE HILL RESERVOIR
KENDALL RESERVOIR
ASNEBUMSKIT POND
TATNUCK BROOK RESERVOIR No 1
TATNUCK BROOK RESERVOIR No 2
Dist. Res Abandoned.
KETTLE BROOK RESERVOIR No 4
KETTLE BROOK RESERVOIR No 3
KETTLE BROOK RESERVOIR No 2
KETTLE BROOK RESERVOIR No 1
LYNDE BROOK RESERVOIR
PARSONS DIST RES
WATER-SHED
WARE CHICOPEE
RIVER
LAKE QUINSIGAMOND
BLACKSTONE RIVER
CHICOPEE QUINEBAUG
BLACKSTONE QUINEBAUG
FRENCH RIVER
TOWN MEADOW BROOK
MIDDLE RIVER
KETTLE
TATNUCK
LINCOLN SQ
WASHINGTON SQ
WEBSTER SQ
BRITTAN SQ
City Engineer's Dept Feb 1912

New England Water Works Association.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

HOW THE WATER EMERGENCY AT WORCESTER, MASS., WAS HANDLED IN THE SUMMER OF 1911, TOGETHER WITH A BRIEF DESCRIPTION OF WORCESTER'S SOURCES OF WATER SUPPLY.

BY FRANK C. KIMBALL.

[*Read March 13, 1912.*]

In the summer of 1911 the city of Worcester, Mass., experienced a water shortage, not to call it a famine. Several possible sources of supply to relieve the stringency were considered, and, while some of them were later used to some extent, it was soon recognized that about the only source which combined both quantity and quality was the Wachusett reservoir of the Metropolitan Water Works, in the towns of Boylston and West Boylston. The nearest available point at which this source could be tapped was about eight miles from the City Hall in Worcester, and at an elevation at high water of about 92 ft. below the street at the City Hall, about 330 ft. below the low-service reservoir supply and about 435 ft. below the level of the high-service reservoirs of Worcester. It, therefore, was a serious question — at a time when the water stringency had become so great that further delay could not be tolerated, — whether the necessary pipes, machinery, etc., could be obtained and installed in season to be of benefit to the city. In fact, at a conference between the State Board of Health and officials of the city of Worcester in Boston, on July 20, the opinion

was expressed by the chairman of that board, that it would be a physical impossibility to get the Metropolitan water into the city in time to be of use.

It was fortunate for the city that it had as its mayor at this time, the Hon. James Logan, a thoroughly trained business man, versed in handling large business enterprises and, therefore, capable of dealing with the important questions involved in an undertaking of this character. Believing that the materials could be found and the work done, all without unnecessary delay if the problem were attacked in the right way, he lost no time in getting in touch with various parties whom he thought might help the city in its crisis. Among others whom he consulted in the matter was the Stone & Webster Engineering Corporation of Boston, who, while not to any material extent operating along water-works lines, suggested certain ways and methods by which it was thought the project could be carried out. Examinations were made by them in behalf of the city, together with some inquiries as to the possibility of obtaining the necessary supplies to prosecute the work.

On Friday noon of August 4, the writer was asked by Mr. F. N. Bushnell, engineering manager of that corporation, to go to Worcester, examine certain proposed routes for a pipe line from Wachusett reservoir to the city, determine the sizes of pipe necessary to deliver over the routes examined not less than 6 000 000 gal. of water daily into its low-service system, and to report in full by the following Tuesday at noon. He spent that afternoon and the following day going over the ground as well as following up the situation in the offices of the city engineer and of the water commissioner, including also several conferences with the mayor and the city attorney, and on Tuesday noon submitted his report to Mr. Bushnell, followed the next day with an estimate in detail of the cost of so much of the work as had been embraced in his studies. This report recommended the route finally adopted but with the further recommendation that certain reinforcing mains be laid by and in the city to supplement those already in place between that section known as "Summit,"— where it was proposed to connect with the city's mains, — and Lincoln Square, where it was required to deliver the water to a 30-in. low-service

pipe. Attention was also directed to the fact that even with these changes it might be difficult to give proper service to certain portions of the city on Burncoat Hill and in the Greendale section if the high-service mains then supplying these sections were diverted from their uses and used to bring in the water for the low-service supply.

Owing to the illness of the city engineer, Mr. Frederick A. McClure, Mayor Logan on Wednesday, August 9, appointed Mr. Charles A. Allen, M. Am. Soc. C. E., formerly city engineer of Worcester and member of long standing in this association, as consulting engineer upon the entire question of emergency supplies of water, he to assume control of all construction required by whatever plans were adopted, and particularly to see that the work was prosecuted to a speedy conclusion. Acting at once in the matter, on the following day he in company with the mayor had a conference at the office of Stone & Webster with members of that organization, at which the writer was present, where all information gathered by that concern was placed at the full disposal of the city and the tender of such assistance as they could render them, made. As one of the results of this conference, on the following Saturday, August 12, the writer was engaged by Mr. Allen to assist him in carrying out the work for which he had been retained, and he immediately went to Worcester for that purpose.

As there was at this time less than 80 000 000 gal. in the low-service reservoirs, and the almost certain necessity was seen of having to use the water in the high service to supplement the low before the Metropolitan supply could be completed, it was early decided by Mr. Allen that any supply brought to the city would have to be under a pressure sufficient to supply the high service as well as the low and of such capacity that, if weather conditions did not help the city, it would be ample for practically the entire daily consumption. Further, as, by so doing, the complications due to attempting to use certain of the high-service mains under low-service conditions would be obviated, the plans finally adopted were upon the basis of pumping 10 000 000 gal. a day into the high service.

It was further decided to take the water, subject to the per-

mission of the Metropolitan Water and Sewerage Board, from a point in Wachusett reservoir in South Bay, near the entrance of Muddy Brook, so called, and where at high water there was a depth of upwards of 40 ft., and to bring the supply into Worcester by way of Hartwell and Burncoat streets, delivering it to the city's high-service mains at West Boylston and Mountain streets in that section of the city known as "Summit." To reduce the friction head as much as possible, a 30-in. pipe line was found to be desirable. Estimates of cost covering the work upon this plan were made and submitted to the mayor on the morning of August 14, and by him transmitted to the City Council that same evening, at which time by resolution, the consulting engineer, Mr. Allen, under the direction of the mayor, was ordered to proceed with the work and do all things necessary to procure and make available at the earliest possible moment an emergency water supply delivered into the high-service mains as above outlined. The estimated cost of this work, $153 000, was, with other amounts, appropriated at this same meeting.

The necessity of changing the plan so as to permit of taking care of the high as well as of the low service, and of providing sufficient capacity to substantially meet the full daily needs of the city, as well as the need of haste in the execution of the work, may be seen from the fact that on August 5, with a daily average consumption in the month of July of about 10 700 000 gal., of which about 4 850 000 gal. came from the high-service sources, and about 5 850 000 gal. from the low service, there was in storage, in the Tatnuck or low-service reservoirs, only about 80 000 000 gal., and in the Kettle Brook and Lynde Brook reservoirs, supplying the high service, about 580 000 000 gal. Thus the low service had only about fourteen days' supply on that date for its portion of the city, after which, if not replenished, the high-service supplies would have to be called upon to supply the entire city. Upon the assumption, fair at this season of the year, — August and September, — that any yield from the watersheds would probably be sufficient only to care for evaporation at the best, the entire supply in storage on August 5, about 660 000 000 gal., after deducting such of it as was not available, would supply the city for from sixty to sixty-five days.

In order that a clear understanding of the situation at this time may be had, a brief description of the various sources supplying Worcester will be of interest.

At this time, all of its water supply is obtained by gravity from three brooks, all tributary to the Blackstone River. These had been developed by the construction of dams across these streams at advantageous points, thus forming seven storage reservoirs. The accompanying map (Plate II) has been prepared through the courtesy of the city engineer's office in Worcester, and outlines these various supplies, indicating as well certain contemplated additional sources from which Worcester expects to draw, as well as showing the various emergency sources utilized in the summer and fall of 1911.

The original source of Worcester's water supply was Bell Pond on Belmont Hill, which in turn was fed by an aqueduct from Putnam's Meadow, so called, to the northeast of this pond. This was the sole supply of the city until the early '70's when the Lynde Brook supply was developed. After Lynde Brook supply was turned on to the city, Bell Pond was used more or less, and particularly as an emergency supply, until about 1898, when it was finally abandoned.

The oldest supply of those now in use is that of Lynde Brook. This has a drainage area of about 2.92 sq. miles and a storage of 700 581 000 gal. From this reservoir is taken all the high-service supply for the city, through the main gatehouse near the lower end of the reservoir. Some distance up the easterly side of this reservoir is another gatehouse controlling the flow through a 30-in. conduit to Parson's reservoir, a distributing reservoir at the same elevation as the low-service reservoir No. 2 of the Tatnuck system. Through this connection the waters of Lynde reservoir may be used for the low service also, the prevailing practice being to take a limited portion of the low-service supply from this source as well as all of the high service. There are likewise several gated cross-overs about the city by means of which the high service can be connected with the low service.

To the west of the Lynde Brook watershed is that of Kettle Brook. This watershed has an area of about 3.62 sq. miles, the storage of which has been developed by four reservoirs with a

combined capacity of 812 362 000 gal. The lower one of these, Kettle Brook No. 1, is connected to the Lynde Brook reservoir by a 30-in. conduit, through which all utilized waters of the Kettle Brook watershed flow.

Draining into Kettle Brook Reservoir No. 1 from the west, but without any independent storage, is Peter Brook, having a drainage area of 0.48 sq. miles. This brook formerly drained into Kettle Brook some distance below the reservoir but is now diverted so as to feed into Worcester's supply. These three brooks combined give a total drainage area of 7.02 sq. miles, with a storage of about 1 512 943 000 gal., all available for Worcester's high-service system and also capable as above described for the low service when needed, being to some extent usually so used.

To the northeast of the Lynde Brook watershed is that of Tatnuck Brook, sometimes called the Holden supply from the town in which it is principally situated. This is used solely for the low service of Worcester, and has a watershed area of about 5.23 sq. miles, with a developed storage by means of two reservoirs of about 986 717 000 gal. without the use of flashboards. Eighteen-inch-high flashboards are sometimes used in the overflow of these two reservoirs only, and when so used, increase their capacity by about 91 190 000 gal. Together, these two systems have a combined watershed of about 12.25 sq. miles with a developed storage when flashboards are used of about 2 590 850 000 gal. and at this time constituted the entire water supply of Worcester.

An examination of a topographical map of this region will show that Worcester is situated in a comparatively high altitude and very close to the divide separating the various watersheds of Eastern Massachusetts. It has, therefore, a somewhat limited area from which to draft a water supply without pumping against high heads. About eight miles northwesterly from the city, in the town of Paxton, is the summit or apex of four different watersheds, where head: Turkey Hill Brook, draining generally in a southwesterly direction into the Chicopee River; Town Meadow Brook, draining southerly into the Quinebaug River; Tatnuck, Lynde and Kettle brooks, draining southeasterly into the Blackstone River; Asnebumskit and Kendall brooks,

draining northerly and easterly into the Quinepoxit River and forming part of the watershed of the south branch of the Nashua River, which in turn, by means of the dam just above Clinton, forms the Wachusett Reservoir, supplying the larger part of the Metropolitan water for Boston and vicinity.

Another watershed, that of Ware River, heads in the town of Rutland, just to the north of Paxton and to the west of the Nashua River watershed.

These are all shown on Plate II and indicate better than can any description the extent to which Worcester had to this date developed all water supplies within what may be termed its territory.

Foreseeing, however, the ultimate necessity of going beyond the Blackstone River shed for an additional supply, Worcester had retained, in Chapter 488 of the Acts of 1895, the original act creating the Metropolitan Water District, the right to take water from the Nashua River watershed under certain conditions. This right was extended and amplified by subsequent legislation in 1897 and again in 1902 when, by Chapter 351 of the Acts of that year, authority was expressly granted to Worcester to take the waters of both Kendall and Asnebumskit brooks under the conditions contained in said Act. Proceeding under the terms of this legislation, while no legal taking of the water had then been made, more or less construction work leading to the development of these sources had been done at this time. Both Kendall and Pine Hill reservoirs as they formerly existed were storage reservoirs, built and maintained by the mills on the streams below, and before being disturbed by the city had estimated capacities of 82 000 000 and 119 000 000 gal. respectively. To this time in connection with the general plan for using these waters, Worcester has constructed a receiving pool, discharging into the head of Tatnuck Brook, a conduit, built partly in tunnel and partly in open cut, through the divide, to and through a gatehouse in a dike, also built at the southerly or upper end of Kendall Reservoir. This dike was required for the purpose of raising the water level higher than the natural divide between the two sheds and providing more storage than otherwise would have been available. The conduit through this dam continues about half way through Kendall Reservoir.

Above Kendall Reservoir and about half way between Pine Hill Reservoir and Eagleville Pond, a diversion dam and headworks have been built across Asnebumskit Brook, and an open conduit or canal, lined with concrete, constructed from these headworks to Kendall Reservoir, into which it discharges.

To digress at this point, it may be stated that the Asnebumskit and Kendall watersheds combined, which will thus be utilized, cover about 9.48 sq. miles, and will, when developed, with the existing watersheds, give Worcester a watershed area of 21.73 sq. miles to draw from. The present plans contemplate the building of a dam at the northerly end of Kendall basin, near the present outlet of Kendall Brook (this dam being at the present time, March, 1912, partially completed) and of a height to materially increase its former storage capacity, together with the extension of the conduit or channel through the reservoir so that it may entirely drain through the divide into Tatnuck Brook. Later and as a part of the same general scheme, it is intended to develop the Asnebumskit Brook watershed by the construction of a new dam near but a little above the site of the present one at Pine Hill and with a flow line at elevation about 902, taking the waters so stored through the channel of the brook to the headworks above outlined, thence through the open channel or canal, discharging into Kendall Reservoir and from there through the conduit into the head of the Tatnuck system. These improvements are expected to give Worcester an additional storage capacity in Kendall Reservoir of about 814 500 000 gal., and in Pine Hill Reservoir of about 2 155 000 000 gal. When completed, Worcester will thus have a total storage of 5 469 160 000 gal., without the use of flashboards, which with its then combined watershed of 21.73 sq. miles should be ample for a population of considerably over 250 000.

On July 1, 1911, the city had in its low-service or Tatnuck reservoirs, about 245 000 000 gal., of which about 225 000 000 gal. were available. On the same date in the Lynde and Kettle Brook reservoirs, the high-service system, were about 749 000 000 gal., 351 000 000 being in the Kettle Brook and 398 000 000 in Lynde Brook reservoirs. Of this quantity about 714 000 000 gal. could be drawn for use. On August 5, as above stated, the total quantity in storage was about 660 000 000 gal., thus showing a loss of 334-

FIG. 1.
HOLDEN NO. 1, FROM UPPER END, SOUTHERLY, AUGUST 1, 1911.

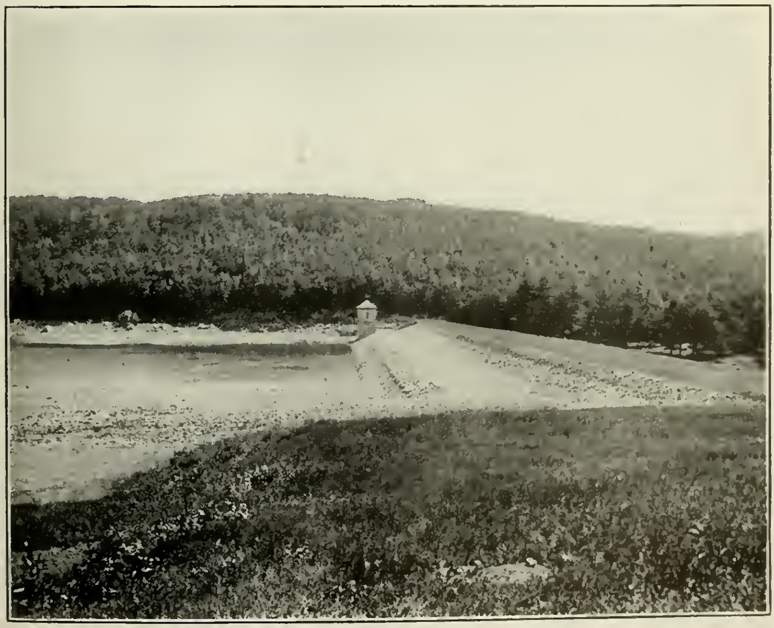

FIG. 2.
HOLDEN NO. 1. LOW WATER AT DAM, JUNE 8, 1911.
Views showing depletion of reservoirs.

000 000 gal. in thirty-six days, or an average of about 9 300 000 gal. per day.

During the month of June, the city had used, in round numbers, 333 000 000 gal., a daily average of 11 100 000 gal.

Thus facing a draft of between nine and ten million gallons per day in excess of yield, on July 1 it was apparent to anyone that Worcester might easily be out of water by October 1st to the 15th. To the mayor, the city engineer and the water commissioner it had been evident long before this time that unless relieved by rains, Worcester was facing a water famine. For several years prior to this date, both the city engineer and the water commissioner in their yearly reports had recommended that steps be taken to permanently augment the supply, and to this end not only had complete plans been prepared but work had been carried forward along the lines of such plans to the extent above outlined, — all that could be done with the means provided therefor. The work had not, however, at this time progressed to a point where it rendered available any addition in quantity to the supply although some considerable portion of the work then completed was of very great assistance in handling certain of the emergency supplies furnished the city later.

The first real official recognition of the existence of an emergency in the water supply by the City Council was made on June 26, when it instructed the water department to take all necessary steps to curtail the use of water, and particularly to see that all hose, street sprinkling, etc., was discontinued. This was done at once, a rigid inspection maintained, railroads were required to obtain their water at other places whenever possible, and such other steps taken as would insure the use of water for absolute domestic and business necessities only. Still the first week in July showed a drop in the storage of approximately 10 000 000 gal. daily. All waters in the upper reservoirs were drawn into the lower ones to reduce evaporation as much as possible. As a preliminary step looking to its use as a possible supply, although at that time having no legal right to the water, the mayor entered into an agreement with the owners of Pine Hill Reservoir not to draw down the water then in storage for the mills below but to leave it for the possible use of the city.

On July 10 the City Council authorized the city engineer and the water commissioner, acting under the direction of the mayor, to take the waters of Asnebumskit Brook, Lake Quinsigamond, and such other available source or sources as in their judgment the exigencies of the city demanded, procuring and erecting all necessary pumping and other machinery, pipes and appurtenances, etc., an appropriation being made for that purpose.

The city of Worcester for over thirty years has kept installed on the shore of Coes Pond, a pumping plant for use in any emergency that might arise, and in that period, although not for a number of years prior to this time, it had been so used. An order had been passed by the City Council as long before as December 28, 1910, to prepare the pumps at Coes Pond for use in case of necessity, and to erect such additional boilers and pumps as might seem desirable, which was done. Coes Pond and Reservoir combined were estimated to hold about 250 000 000 gal. of available water, and it was all along thought it could be used to help Worcester out of its troubles. On January 5, 1911, the State Board of Health approved the use of these waters in the event of a drought, although as a matter of precaution recommended that the inhabitants be cautioned to boil the water before drinking. This permission was reiterated by the board on March 28, and the officials of the city had been relying largely upon this source to relieve any stringency that might arise. However, so much public sentiment had been created against the use of this water that on July 20, at the conference before mentioned, the State Board of Health decided that this water could not be used except as a last resort, and as a consequence a complete change in plan was necessary.

Lake Quinsigamond waters could not be used directly from the lake on account of pollution due to the state hospital on the hill to the west, and also that due to the cottages and places of amusement surrounding the lake. Consideration, however, was given to driving wells near the shore, thus obtaining benefit of ground infiltration as well as of such water as might otherwise be obtained from the wells. The question of the installation of filter beds and other means of purification were likewise considered, but the time required for these latter schemes appeared to make them im-

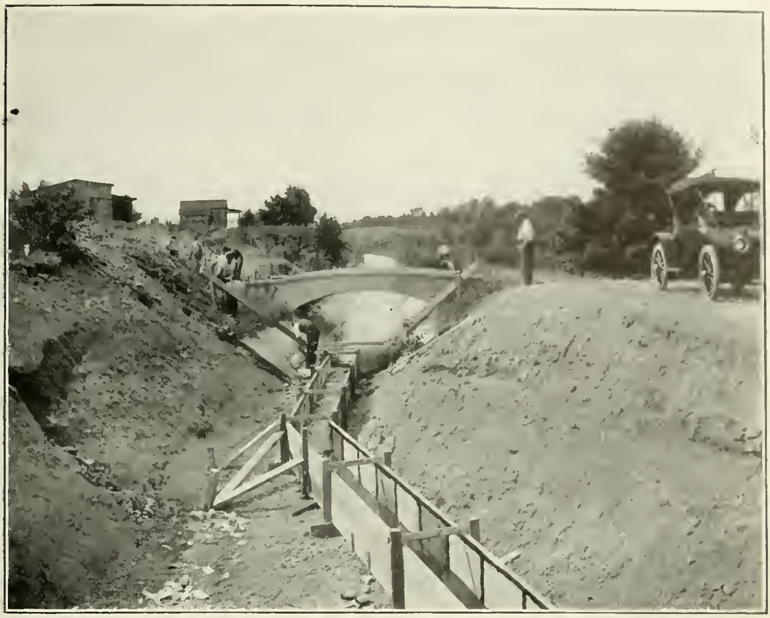

FIG. 1.

UPPER END OF SLUICE AT END OF DODD ROAD, LOOKING NORTHERLY UP CANAL. AUGUST 1, 1911.

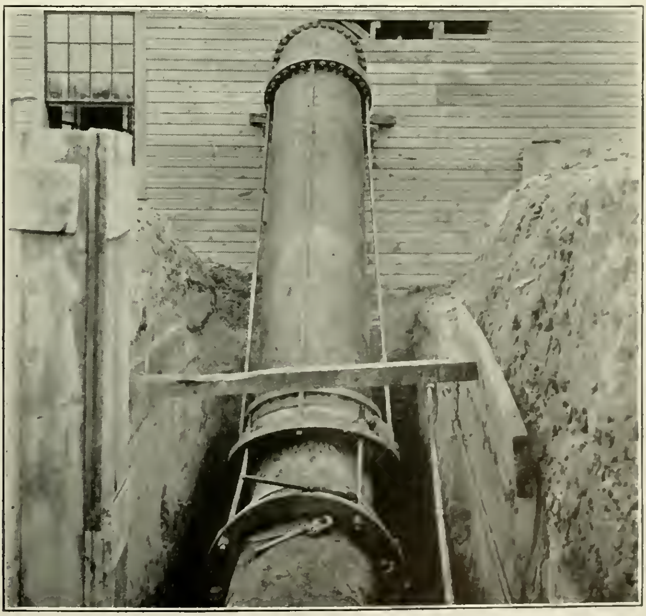

FIG. 2.

30 INCH DISCHARGE PIPE FROM PUMPING STATION ON WACHUSETT RESERVOIR, SHOWING TIE-RODS IN PLACE.

practicable, and as, in the experimental wells sunk, much rock, bowlders, etc., were encountered, it was finally decided to abandon further consideration of this source.

The waters in Pine Hill Reservoir being unhesitatingly approved by the State Board of Health, steps were taken at once to complete the channel in the upper end of Kendall Basin so as to permit of the flow of these waters to Tatnuck Brook. As the water could not be turned directly into Kendall Basin from the canal without flooding the construction work then in progress along the lines of the permanent plans, and as it also could not be held in the basin, with the old outlet dam removed and the new one not built, without considerable cofferdam work, it was decided by the city engineer, with the approval of the mayor, to build a wooden flume or sluiceway, following somewhat the contour of the basin, from the southerly end of the canal from Asnebumskit Brook to a point where the conduit from Tatnuck could receive the water and keep it confined within its banks, a distance of about 4 700 ft. Accordingly a contract was negotiated by the mayor on July 20, immediately after returning from the conference with the State Board of Health in Boston, for building the same. The sluiceway as designed had a safe carrying capacity of upwards of 8 000-000 gal. per day. This work was finished August 1, and on that day water from Pine Hill Reservoir was first let into Worcester's water system.

An examination of the ground and a report thereon by Prof. W. O. Crosby, geologist of the Massachusetts Institute of Technology, encouraged the city in the belief that water could be obtained from the basin of Kendall Reservoir by means of wells, and some sixty shallow wells of $2\frac{1}{2}$ in. pipe were driven in the bottom of this basin. These wells ranged from 24 to 32 ft. in depth, penetrating a coarse sand in nearly all instances. Two gasolene pumping engines were obtained, the wells connected up to these, and the water so obtained pumped into the same sluice which carried the waters from Pine Hill Reservoir. Pumping from these wells continued until about the first of October, when, a vacuum of from 22 to 24 in. being required to raise the water, pumping ceased and this source was abandoned.

When Mr. Allen assumed charge of the emergency work the

sluiceway had been built and the city committed to the driving of the wells in Kendall Basin. Believing as he did that with all the water then in sight, including the 119 000 000 gal. in Pine Hill Reservoir, such reserve as could be obtained from Asnebumskit Brook and Pond above Pine Hill and with what could be pumped from these wells, it all was likely to be exhausted before the Metropolitan supply could be made available, he further recommended to the mayor and through him to the City Council at its meeting on August 14, that authority to take the waters of Eagleville Pond be given, — this having an available estimated quantity in storage of about 240 000 000 gal.,— that pumping machinery be erected and a pipe line laid from this pond to the lower end of the canal on Dodd's Road, so called, where the wooden sluiceway joins this canal, to enable this pond water to be pumped into the flume. An appropriation of $21 000 was asked for this purpose, which was voted and the authorization to take the waters granted.

Thus, on August 14, only five days after his appointment, appropriations had been made, based upon plans and estimates worked out in that time by Mr. Allen with the writer's assistance, and the work ordered forward. It may at this time be pertinent to say that the Metropolitan job, so called, which of course was the important one, estimated to cost $153 000, actually did cost $153 626.29, as shown by the city auditor in his annual report to the City Council at the close of 1911, being within about four tenths of one per cent. of the estimate. This is mentioned only to emphasize the fact that although the time was extremely limited, the work was carefully planned, estimated, and then constructed in fairly good accord with such plans. It is further pertinent to state that while the general scheme was well in hand and inquiries had been made as to where and how soon some of the machinery, pipes, etc., could be obtained, none had been purchased nor contracts let at the time the appropriations were made and the final order given by the City Council to proceed with the work.

The Eagleville Pond supply was placed under the immediate charge of Mr. Samuel H. Pitcher, M. Am. Soc. C. E., formerly of the city engineer's office of Worcester, and a member of this Association. Three pumps, obtained from stock on hand of the

Deane Steam Pump Company, of Holyoke, Mass., were erected in an old power house of the Worcester Consolidated Street Railway Company, which was advantageously situated upon the shore of this pond. The Railway Company also had a couple of boilers at their Millbury power house, not then in use, which were of suitable size for this work, which they loaned to the city. These were erected in this power house, and thus at comparatively small expense a temporary pumping plant was installed. The pumping head including friction with all three pumps running was about 120 ft., the capacity being about 4 500 000 gal. per day.

A 12-in. force main was laid, about 4 900 ft. long, from this power house to the sluiceway as above described, about a third of the way being across private property and the remainder of the distance in Dodd's Road, so called. The larger part of this pipe was from the stock of the Worcester Water Department, supplemented by some found on hand at one of the foundries from which quick delivery was had. Several contractors were asked to submit bids for laying this pipe, two being received; but as the lowest of these was for $1.50 per ft., both were rejected and the Water Department laid it with their own force and at a cost of a fraction under fifty cents per foot. The entire work was completed and pumping began on September 27, twenty days after actual work was started on this job. The total cost of the Eagleville Pond supply, as given by the city auditor in his annual report, was $18 044.22, — $2 955.78 under the estimate.

From the moment of the passage of the necessary orders by the City Council on August 14, work proceeded as rapidly as possible upon the principal emergency job, known as the Metropolitan supply. While the matter had been discussed with them before the first of August by the mayor, and it was tacitly understood that permission would be granted by the Massachusetts Water and Sewerage Board to take water from Wachusett Reservoir, formal permission was not granted until August 28. Work, however, was not delayed on this account.

Within about 1 500 ft. of the selected location for the pumping station upon the shore of Wachusett Reservoir, and crossing the proposed pipe line were the high-tension lines of the Connecticut River Transmission Company, carrying electric current under

65 000 volts pressure. This was one of the controlling factors determining the use of electrical machinery to operate the power station, — other considerations being the lesser cost of first installation as compared with steam pumping engines, boilers, etc., smaller and consequently less expensive buildings and foundations, quicker delivery of machinery and more cleanliness in operation, — this latter factor being important particularly to the Metropolitan Water Board, owing to the location of the plant. Cost of operation by electrical power was not analyzed for this particular job, but was considered to be at least as cheap as steam power, owing to the distance coal would have to be hauled and the lesser amount of labor required to operate an electrically driven station than would be the case with a steam plant of the required capacity, which was about 1 500 horse power when pumping at a ten-million-gallon rate against a pumping head of 550 ft., these being the conditions to be met.

On August 15, the day following the authorization of the work, a contract was closed with the Alberger Pump Company of New York for 3 two-million-gallon, 4-stage turbine pumps, guaranteed to operate at this capacity against the full head of 550 ft. Shipment was promised of the first unit September 5, the second on September 9, and the third September 12, — all with a forfeiture and bonus clause. The average date of actual shipment was the exact contract date. The Alberger Pump Company also gave the city options on two additional pumps of the same type and at the same price, with a delivery of four weeks after receipt of order. Taking some chances on weather conditions, it was decided not to order these additional pumps until later, but this was the only departure from the full 10 000 000 gal. capacity required, in the machinery, pipes, etc.

On August 15 contract was entered into with the Connecticut River Transmission Company for power to the maximum demand of 800 k.w. with options under certain conditions to increase it to 1 300 k.w., this to be delivered at the pumping station in the form of 3-phase, 60-cycle, 13 200-volts alternating current. As the actual quantity of current desired was largely dependent upon weather conditions, no minimum rate or consumption was guaranteed, but in lieu of a minimum, the city agreed to pay for certain

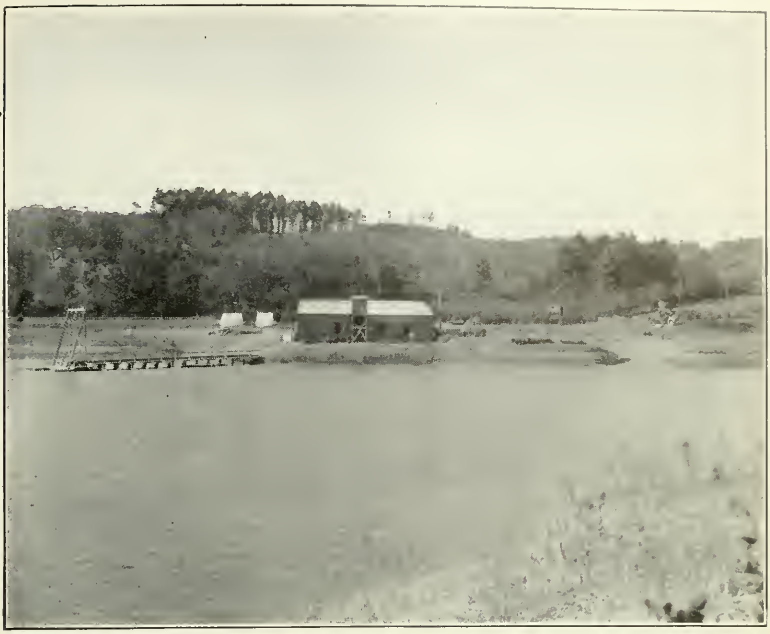

FIG. 1.
VIEW OF PUMPING STATION.

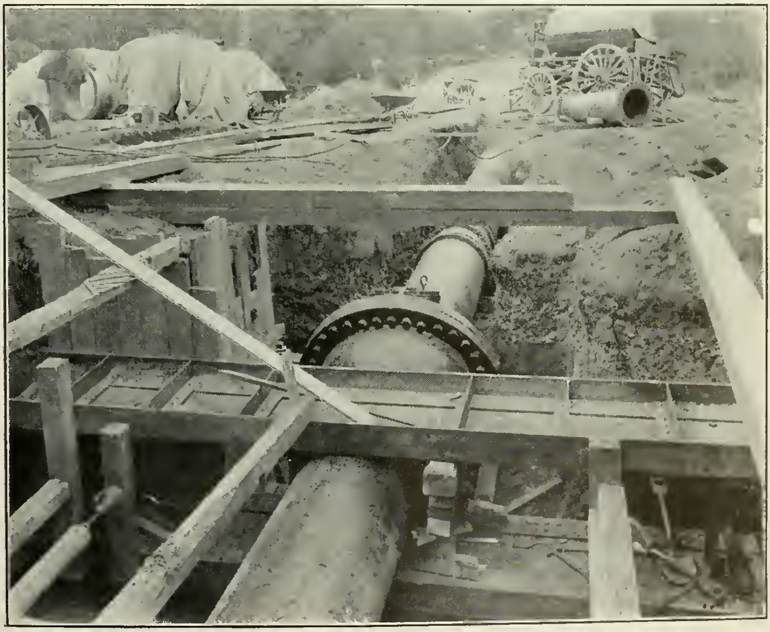

FIG. 2.
30-INCH CHECK-VALVE.

additional construction required to be done by the Connecticut River Company to carry out this contract, such to remain its property. The city also paid all costs of bringing the power from the company's lines to the pumping station.

On August 23 a contract was entered into with the General Electric Company to furnish the electrical outfit, consisting of 5 250-h.p. motors, with starting devices complete; 3 210-k.w. air-blast transformers; 2 blowers; 9 100-k.w. oil-cooled transformers; 1 lightning arrester equipment; 1 feeder and 5 motor switchboard panels. This material was to be shipped at varying intervals ranging from ten days to four weeks, except in the case of 1 blower requiring six weeks, 1 motor eight weeks, and the 9 100-k.w. transformers, ten weeks for delivery. All of this material was shipped and received as contracted for. To provide for transformers, — the only part of this apparatus that might cause delay, — an arrangement was entered into by the Connecticut River Transmission Company with Crocker, Burbank & Co., of Fitchburg, Mass., for the use by the city, for two months, of three large transformers they had, suitable for this work, thus tiding the city over the delay incident to receiving its own.

On August 24 a contract was signed with the Stone & Webster Engineering Corporation, to erect and install the pumping machinery complete, including the building, suction pipes, intake chamber and screens, and all discharge connections to the outside of the building. This covered also the preparation of the plans of the electrical installation and the inspection, etc., of the machinery furnished, all subject to Mr. Allen's general supervision. Under this contract ground was broken on September 12 at the pumping station, and on October 22, forty days thereafter, water was being pumped with everything in complete working order.

Coming now to the pipe line, on August 16, a contract was entered into with F. A. Houdlette & Son, Inc., of Boston, to furnish all cast-iron pipe and special castings required, including all flanged work at the pumping station. This contract called for 12 600 ft. of 30-in. pipe of classes D, F, and H of the New England Water Works Association Standard Specifications; 480 ft. of 24-in. Class D pipe; and 1 500 ft. of 12-in. pipe of Classes C and H. Shipment was to commence August 19, and to average 1 200

ft. per day until the entire quantity was shipped. It should be borne in mind that all this pipe had yet to be cast except about 173 lengths already on hand, which the city agreed to accept. The specials and flanged work were to be shipped within three and four weeks after receipt of specifications. The first shipment of pipe was made on August 17, one day after signing the contract, and the last shipment (except two cars shipped September 14) on September 8. The first car to arrive at Worcester was on August 31, and the last car September 27. Some few special castings came later but did not materially delay the work.

On August 18, contract was closed with the Builders Iron Foundry, of Providence, R. I., for a 30-in. Venturi meter, with 10-in. throat, together with a combined register-indicator-recorder, all to be delivered within four weeks. This meter was necessitated by the agreement with the Metropolitan Water and Sewerage Board, which required payment for all water taken by the million gallons. This meter arrived in Worcester two days ahead of schedule time. When setting the Venturi tube, it was discovered that the two sections on the outlet end were defective. This discovery was made just as they were about to be placed in the pipe line one Wednesday afternoon, at about three o'clock. By the use of the telephone, supplemented by a trip of the writer to Providence that night and a personal conference with the officials of the foundry, these two specially designed castings, for which patterns had to be made, were put through and delivered to a motor truck on the following Saturday evening and delivered on the work on Sunday morning, being set in place that same day.

This was only one of the numerous uses made of auto trucks as well as of automobiles in the prosecution of this work. The automobile used by the engineers had a record of over 3 600 miles in a little under ten weeks' use, frequently being employed from twelve to fifteen hours of the day. Its use undoubtedly more than doubled their radius of action, and to-day this means of locomotion is well-nigh indispensable under modern construction methods.

On August 21, a contract was closed with the Chapman Valve Company for 3 30-in., 1 24-in., 3 12-in. flanged, and 5 6-in. blow-off gates, all to be delivered within three weeks, which contract likewise was fulfilled on time.

On August 19 a contract was made with the Ludlow Valve Company for 1 30-in. swing-flap check valve; 3 12-in. extra heavy check valves for working pressure of 240 lb., and 3 12-in. foot valves for the suction pipes, also to be delivered within three weeks. On August 22 a contract was closed with the same company for 1 30-in. check valve, to be built for a working pressure of 230 lb., to be delivered in as much under six weeks as possible. In connection with this check valve, which weighed 13 900 lb., was another of the quick movements of the job. All of the pipe and most of the other carloads of freight had come over the Boston & Maine Railroad, and several times delays had occurred which had caused the question of deliveries to be taken up direct with the superintendent of that division of the railroad. About a week before this check valve was ready to ship, acting upon information from the factory, we notified the superintendent that it would be delivered to his road at Troy, N. Y., on Saturday afternoon, September 30, and that it was wanted as quickly as he could get it to us. It was loaded at Troy that Saturday at about 3 P.M. and at six o'clock on Sunday morning it was in the Worcester freight yard. While this was the quickest freight delivery on this job, — possibly it is safe to say on any other as well. — still it was only one of many acts which contributed to hurry forward the work, not alone on the part of the railroads but of all others connected with the job.

On August 15, specifications having been prepared, proposals were invited for teaming and laying the pipe and appurtenances. While these were not advertised owing to lack of time, six parties thought to be equipped to handle this work were asked to bid. From these four bids were received and opened on August 18. These ranged in amount from that of E. D. Ward, of Worcester, who was the lowest bidder and to whom the contract was awarded, at $34 605, to the highest bid of $52 350. Mr. Ward, while a contractor of large experience in building work, excavations, etc., had never laid any pipe, and for this reason alone there was some question as to his ability to carry forward the work in the time allowed for it. However, it was finally decided to award the contract to him, largely, perhaps, because — from the nearness in price of all the other bidders as well as the amount of their bids,

nearly fifty per cent. above the engineer's estimates — it looked as though there might be a combination among them. At the close of the work, whatever may have been the opinion at the start, there was no question but that this contract had been wisely awarded.

This contract required the work of laying pipe to begin within forty-eight hours after the first carload arrived in Worcester, and to average laying complete nine hundred feet per day. The contractor did not keep up with this schedule, as rainy weather interfered with the work soon after he was well started. In this case, as each day's rain gave Worcester from two to four days additional water supply, such causes of delays were blessings than otherwise. Had the weather been as dry in September as it was in June and July, this work, finished as it was in record time, could have been done in at least two weeks less time. With a rainfall in August of 5.15 in.; in September, 4.10 in.; and in October of 5.48 in., it seemed as though as soon as the city was tied up in contracts and the work under way, rain was almost interminable.

Mr. Ward broke ground August 28, and laid the last piece of pipe October 16. October 17 to 19 were employed in filling the pipe line, when a cracked pipe developed. This was replaced and proved to be the only defect in the entire work. The line was completely filled by the 21st; machinery and pipes were tested out by the pumps on the 22d; and on the 24th of October, in the presence of the mayor, members of the City Council, and others interested in the work, the pumps were officially started by Mr. Frederick H. Lucke, chairman of the water committee of the City Council. It was found that by running one pumping unit, a capacity of about 3 000 000 gal. was obtained; with two units, about 5 000 000 gal., and with the three units, about 6 500 000 gal., thus somewhat exceeding the requirements. Quite likely had all five of the units contemplated been erected and operated at the same time, the additional friction head would have reduced the output to about the 2 000 000 gal. average for which they were guaranteed. The observed pressures when operating were respectively, 187, 204, and 218 lb., with one, two, and three units running.

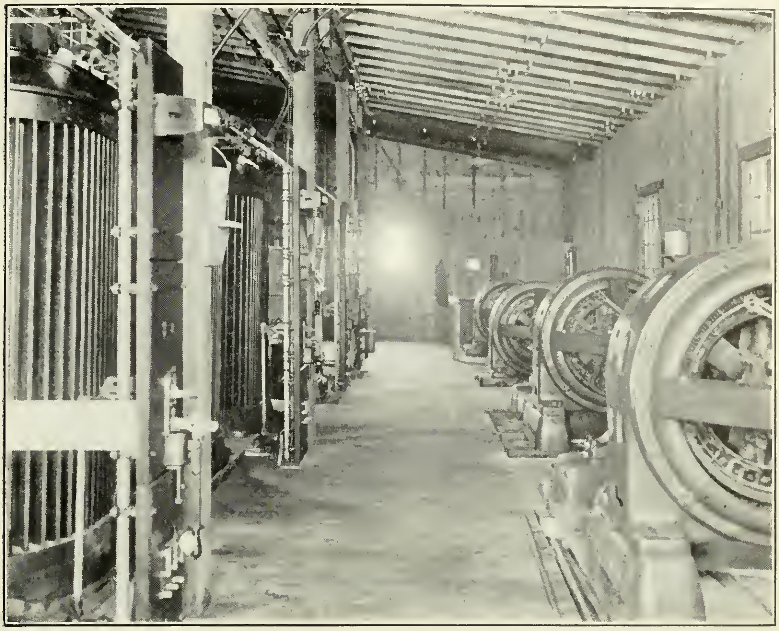

FIG. 1.

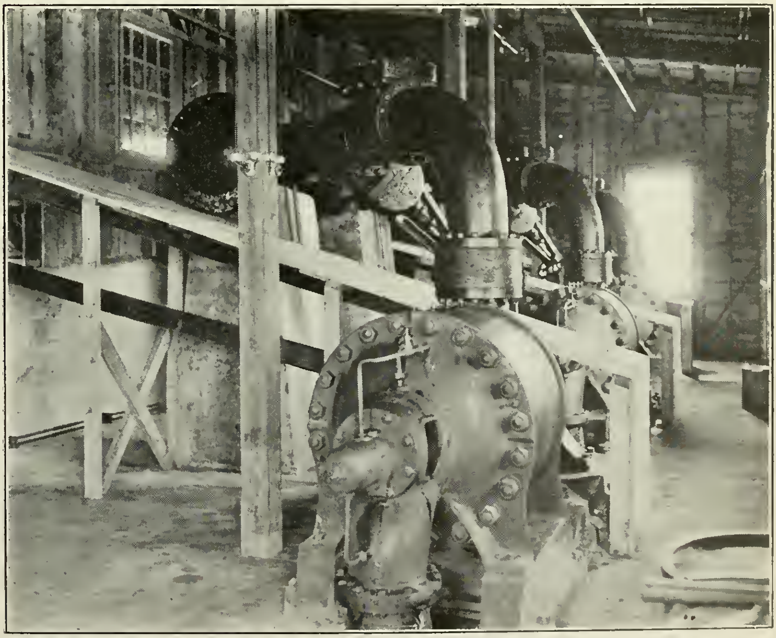

FIG. 2.

INTERIOR VIEW OF PUMPING STATION, SHOWING MOTORS AND PUMP.

Thus, in two months and ten days after the City Council made the appropriations for this work, it was in excellent running order. As before stated, had weather conditions been favorable and thus required it to have been done, the time could have been shortened to somewhat under sixty days. As it is, when the capacity and weight of the work is considered, it is perhaps a safe assertion to make that it was one of the quickest jobs on record, if in fact it did not break all records. Every one took an interest not only in the work itself but in attempting to make it a record job, and its success is largely due to the lack of friction of any kind between the engineers and contractors. No hair-splitting questions were raised on either side, and whenever difficulties presented themselves they were solved with the one idea of good work and expedition, while the question whether or not it would add to or take away from the profits of any particular contract was not considered or thought of. This job also is a good illustration of what can be accomplished when construction work is unreservedly placed in the hands of engineers unhampered by outside considerations. Civil service rules and city ordinances regulating the employment of labor or the letting of contracts were suspended for this work, and Mr. Allen was given free rein to proceed as he choose; in fact, it was only upon these conditions that he accepted charge of the work. Mayor Logan also fully supported him in all questions arising, thus materially assisting in preserving a full degree of harmony during the progress of this and other portions of the emergency work.

There were only a few engineering problems of moment connected with this work, and these hardly worthy of mention. The use of centrifugal pumps, belt connected to electrical motors and operated under the extreme head it was here subjected to, is certainly unusual in water-works practice, yet in this case it seemed to be a satisfactory combination. In ordering the pipe, knowing from experience that in pipe of this diameter more or less of it was certain to be cast eccentric as to thickness of shell, and further realizing that rejections must be limited to the least quantity consistent with obtaining satisfactory results on account of the limitations in time, the pipe was specified about one class heavier than otherwise might have been used. Even then care

was taken in sorting out all pipe as it arrived and distributing it in accordance with its actual thickness of shell on the thinnest side, rather than by its normal class or weight. With an elevation of the pipe line at the reservoir of about 380 and of about 692 where it crosses the divide between the Nashua and Blackstone watersheds, there was sufficient range of pressures to care for about all the varying thicknesses of pipe that arrived. While this method is not economical in ordinary work, its adoption here saved considerable time on this job.

Two 30-in. check valves were used on this line, — one at Summit to avoid emptying Worcester's piping system in case of a break in the 30-in. line, and another near the pumping station to guard against a serious washout in case of accident to the pumps or to the pipes within the building. This latter check valve was set only about 26 ft. from a 45-degree bend where the pipe changes its horizontal direction so as to approach the pump house. To properly anchor this check as well as the pipe line itself at the foot of a rather steep hill, and to take the thrust of any water hammer off the bends, the pumps, and the discharge header within the pump house, a steel grillage or framework was designed and built by the Eastern Bridge and Structural Company, of Worcester. This framework was about 18 ft. long and was set at right angles with the pipe line, being about 2 ft. 10 in. wide along the line of the pipe. It consisted of two girders, one above and one below the pipe, connected together by an octagonal grouping of I-beams so spaced that, with an opening just large enough for the barrel of the pipe to pass through, it engaged the bell of the check valve in nearly all of its circumference. This framework was solidly jacked against the face of the bell of the check and the whole firmly anchored in place by mass concrete. The pressure against this check, when pumping at the rate of 10 000 000 gal. per day was assumed to be about 75 tons, and, to allow for water hammer due to a sudden interruption of the power, the stoppage of the pumps, the blowing off of a bend or from any other reason, the anchorage was designed to withstand four times that pressure, or 300 tons.

All bends, both horizontal and vertical, were thoroughly supported and embedded in concrete, those at and near the pumping

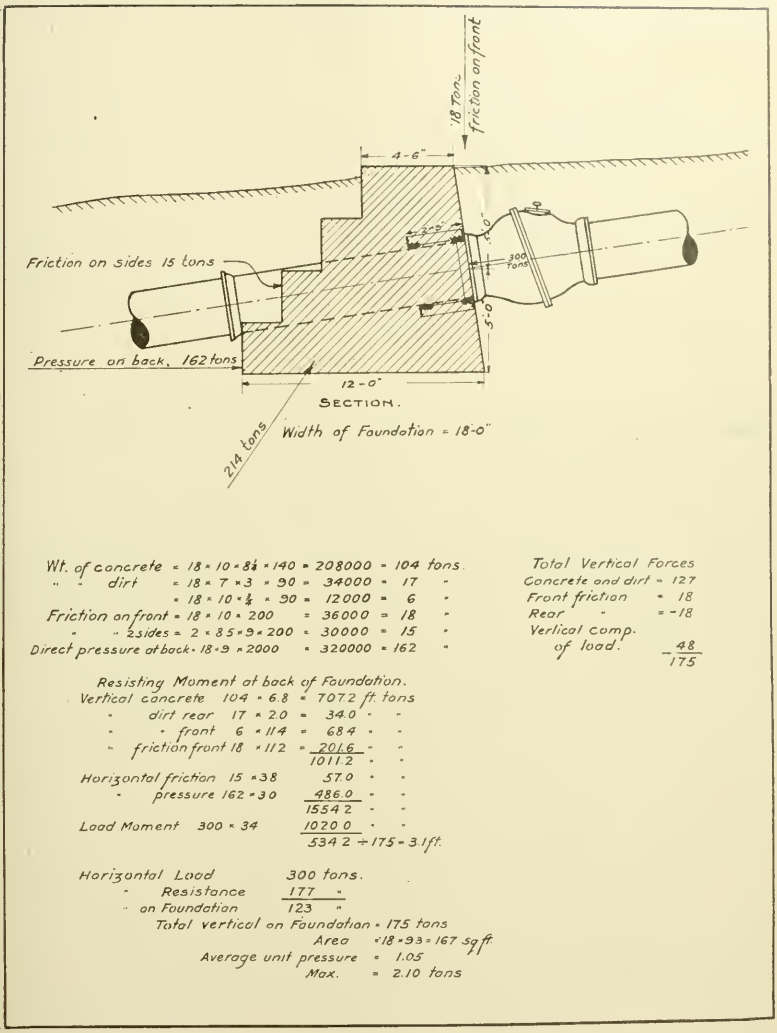

FIG. 6.

CONCRETE ANCHORAGE FOR STEEL FRAME BRACING TO 30-INCH CHECK VALVE.

station being tied together with clamps, rods, and collars, proportioned to take about double the strain due to the full pumping head.

The Boston & Maine Railroad was crossed twice underneath, and, owing to its requirements as to cover, it was necessary to go to a depth of about 8 ft. to the bottom of the pipe, under their tracks. This in one place, owing to steep banks on the side of their right-of-way, required a cutting of upwards of thirteen feet. In both crossings, water was encountered, and in the deeper one a rather quick-running sand gave the contractor considerable trouble. No interruption of trains was allowed, and the work was carried forward to the satisfaction of all concerned.

This article would not be complete without mention of the work done by the water department of the city while this job was under way. To enable the city to avail itself of this supply, numerous changes in and additions to the pipe lines in the city between Summit and Lincoln Square had to be made, and while these were all in harmony with the well-designed piping plan of the city, except for this purpose all these changes would not have been made for a year or two at least. Between August 14 and October 21, the water department with their own forces laid about 12 860 ft. of 16-, 20-, and 24-in. pipe for street mains, practically the same quantity in length as was laid under Mr. Allen's direction from Wachusett Reservoir to Summit; this in addition to that laid by them on the Eagleville Pond line and also in their regular work, which was not materially interfered with. While this in itself would be something of a stunt for most of us, still those who know the capacity for work of our President can easily understand that with him it was simply good exercise. He also was of great assistance at all times to the various contractors as well as to the engineers, and never was so busy that he could not find time to help them out of their difficulties. To him is due the credit for a large measure of the success of the enterprise.

The pipe line work was under the immediate charge of Mr. Arthur E. Tucker, of the city engineer's office, who also by his handling of the work, particularly with a contractor new to pipe laying, is deserving of much credit.

The city as well as the engineers feel under great obligations to the Stone & Webster Engineering Corporation for options on machinery, pipe, etc., which they turned over to the city without cost, and also for their assistance in every way possible in the carrying out of the work.

Owing to the heavy rains which prevailed during October, it was not necessary to use the supply from the Metropolitan source to any extent, and after it had been thoroughly tried out, pumping about 60 000 000 gal. into Worcester's system, it was shut down and now remains in place, awaiting such other uses as it may be put to. In his address to the City Council at the close of his term of office, on December 27, 1911, Mayor Logan among other things said:

"I now offer the suggestion that this pipe line be not taken up, but that the pumping plant and pipe line be kept intact and ready for use as an insurance in case of necessity to strengthen the high-service system. If this is not done, the city must begin at once to consider other sources of supply to strengthen the high-service system, which means a large expenditure of money. If an arrangement can be entered into with the Metropolitan Water Board to allow this pumping plant to remain, the city of Worcester may not be obliged to add to its high service for many years to come, and the interest on present investment for an emergency supply will be as nothing compared to the interest charges which the city must provide for if obliged to build additional reservoirs and construct pipe lines to connect with our present high-service system."

It may thus happen that the full value of the work will be repaid to the city, even though it has not yet been necessary to utilize it to any considerable extent.

Nevertheless, based simply upon its proposed and intended use, it can hardly be said that the work was otherwise unnecessary, as the conditions in August and earlier demonstrated the need of just such insurance. The records at Lynde Brook showed, from January 1 to July 1, 1911, a rainfall of only 15.19 in., — lower than during any corresponding period for years. Further, it may be interesting, as showing what would have happened to Worcester had none of the emergency supplies as furnished been availed of, to call attention to the quantities so yielded to the close of

October, when the rains made further contributions from outside sources unnecessary. These quantities were:

From Pine Hill Reservoir and Asnebumskit Brook	585 000 000 gal.
From wells in Kendall Basin	60 000 000
From Eagleville Pond	62 000 000
A total of	707 000 000 gal.

On October 15 the Worcester reservoirs had

In the two Tatnuck reservoirs	120 000 000 gal.	
In the four Kettle Brook reservoirs	103 000 000	
In the Lynde Reservoir	309 000 000	
A total of		532 000 000
Being less by		175 000 000 gal.

than the emergency supplies had furnished.

Had the months of September and October been as dry as all indications earlier in the season pointed to, Worcester's reservoirs, in spite of all the contributions they could have received, would have been very close to empty when the Metropolitan supply could have been ready for use.

DISCUSSION.

THE PRESIDENT. The water department and the city engineer's department had tried for many years to get an appropriation sufficient to provide this new water supply, but the progress had been very slow. It was hard to awaken the public conscience to the necessity of increasing the supply, so long as water continued to run from the faucets. But conditions had reached such a point, during the fall of 1910 and the winter of 1911, that the speaker was unable to take his regular morning bath with any comfort. Mr. Kimball came to Worcester and assured me that I could do so, but while I believed fully in him I did not do it until I saw that something was doing on the Metropolitan System. It took a long time to get a start. I think for something like seven or eight years we had been trying to get an appropriation,

and I doubt very much if the work would have been carried on as far as it has at the present time if it had not been for the shortage of water in 1911. I think the work of developing the emergency supply was done in remarkably quick time, and it shows how men of ability, unhampered by Civil Service rules and, I might say, by politics, can go ahead, when sufficient appropriations are made, and prosecute a work. We are maintaining the pumping plant at the Wachuset Reservoir in condition for operation, and shall do so probably for a year or more, until we have more fully developed our present supply.

THE ECONOMY OF CIRCULAR REINFORCED CONCRETE RESERVOIR CONSTRUCTION.

BY ALEXANDER POTTER, C. E.

[*Read by title, February 14, 1912.*]

The economy in constructing service reservoirs, circular in shape, for water-works purposes is not, in the opinion of the writer, appreciated as fully as it should be. The circular shape for small reservoirs is not only the safest type of construction from a structural standpoint, but permits also a more economical use of the structural materials. Among the many and, unfortunately, only too frequent failures in reinforced concrete construction, it is rare to note failures of circular reinforced concrete tanks, other than those of badly leaking tanks due to either poor workmanship or poor design, or both.

One of the greatest advantages possessed by the circular section and not possessed by any other is the ability to increase economically the capacity of such a reservoir by simply increasing its depth. This is of great importance in the design of water-works improvements, for it enables the designer to keep down the first cost of construction by building a reservoir of a size sufficient for the immediate needs. As the water consumption increases, it is possible to increase economically the capacity of the reservoir, and at the same time raise the water level to counteract the increasing frictional losses in the distribution system due to increased consumption.

The design of a circular reinforced concrete reservoir appears to be so very simple that the inexperienced designer, carried away by his enthusiasm, is apt to create a structure of larger diameter than the application of the simple formula of tank design would seem to warrant. To him there appears to be no ostensible reason why a structure twice the size of one already built should not offer every evidence of strength and stability if designed in

accordance with the formula for ring tension,—a very misleading deduction. The secondary stresses, which in small structures are insignificant, and consequently deemed of too little importance to have attention called to them, increase rapidly with the size of the structure, and only too often limit the size to which any particular type of construction can be adapted.

In a circular reinforced-concrete tank, the writer has in mind the varying tension from point to point in the steel reinforcement due to the difficulty of obtaining a true circle in the field. In a small tank, this is not so serious, as its effect upon the resultant stresses in the steel reinforcement is so slight. To make this point clear, some computations have been made by the writer based on the assumption that in the construction of this type, even with the best of care taken in the field, a variation of a half-inch in the middle ordinate of a 10-ft. chord is likely to occur.

Radius of Tank.	Variation in Radius of Curvature due to a Variation of 1/2 in. in Middle Ordinate of a 10 Ft. Chord.	Corresponding Range of Tension in Steel Reinforcement. Average Unit Tension equals 14 000 Lb. per Sq. In.
Feet.	Feet.	Pounds.
25	23.0– 27.2	12 860–16 200
50	42.8– 60.1	11 950–19 100
100	74.9–150.5	5 910–21 100
200	120.2–632.0	5 820–44 500

This table is not made to accurately show the variation in the tensile stresses of the steel reinforcement for the various diameters given; it does, however, give a fair idea of what may be expected in the variation of the ring tension in a circular structure. It points out the danger resulting from carelessness in constructing a circular reservoir of comparatively thin wall section more than 100 ft. in diameter. For reservoirs of large diameter, however, the economy resulting from the use of a circular section does not obtain to the same extent, and consequently recourse to this type is not so frequent.

The writer's experience would tend to limit the working tension in the steel reinforcement to 14 000 lb. per sq. in. in a small tank, and to 12 000 lb. per sq. in. for comparatively large tanks. A reduction in the allowable steel tension for large tanks is recommended because of the greater range in the ring tension present in the larger structure. It may even be advisable to reduce the allowable unit stresses below 12 000 lb. per sq. in. to keep the excessive local stresses which cannot be avoided within safe limits.

The variation in the tension of the steel reinforcement from point to point, due to the varying curvature of the shell, makes the use of a reinforcing bar with mechanical bond advisable. The reinforcing bars for this reason should also be of as small a size as it is possible to handle economically in the field.

A high carbon steel with an elastic limit of 50 000 lb. per sq. in. can be used to great advantage.

Another difficulty to be considered in the design of a circular reservoir is the tendency to rupture along the line between the inside wall of the reservoir and the base, due to the expansion of the walls by internal water pressure and the consequent drawing away, as it were, from the base of the tank.

A good example of increasing the capacity of a circular reservoir is the enlargement of the distribution reservoir for the village of Suffern, N. Y. This village takes its water supply from Anthrim Lake, formed by impounding a branch of the Ramapo River. The water is pumped from this lake to a distribution reservoir located on the side of a mountain to the north of the village, about 180 ft. above the average village datum. This distribution reservoir, built a number of years ago, is a circular tank 70 ft. in diameter and 10.5 ft. deep, sunk entirely into the ground. The walls forming the sides of the tank are 2 ft. thick, and both bottom and sides are constructed of plain concrete. This reservoir had a storage capacity of 266 000 gal., and cost approximately $4 000.

The recent growth of the village has made it advisable to double the capacity of this distribution reservoir. The old structure, although massive, nevertheless leaked to a considerable extent, especially in the bottom. It was, therefore, decided to line the bottom of the tank at the same time that the sides were being

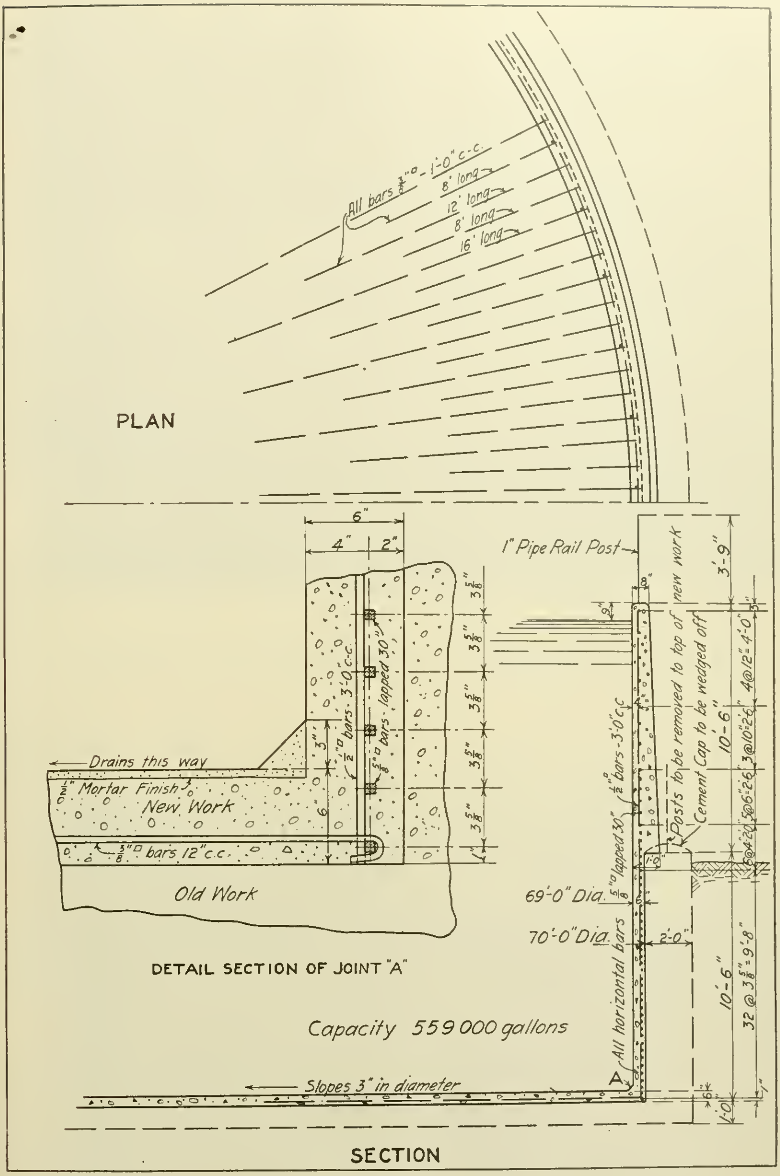

Fig. 7.

Reservoir at Suffern, N. Y.

raised. The reservoir as remodeled has an inside diameter of 69 ft. and holds approximately 20 ft. of water, giving a storage of 559 000 gal. The side walls of the old tank are lined on the inside with 6 in. of reinforced concrete. Above the old work, the width of the new work is 12 in., tapering to 8 in. at the top. (Fig. 7.)

The circumferential reinforcement consists of $\frac{5}{8}$-in. square corrugated bars, possessing an elastic limit of 50 000 lb. per sq. in. These bars are so spaced that the average unit tensile stress in them does not exceed 14 000 lb. per sq. in.

In designing the lining for the old reservoir, it was assumed that the reinforcement would only have to take care of the increased tension due to the additional depth of 10.5 ft. This is a constant quantity with a full reservoir; consequently the spacing and size of the steel in the lining of the old reservoir is uniform. The existing wall is still relied upon to resist the hydrostatic pressure that it formerly did.

It is not very likely, because of the great daily fluctuation in the water level in this reservoir, that ice pressure will develop to such an extent as to seriously over-stress the reinforced concrete shell, and consequently, no provision has been made for such pressures.

The bottom lining is reinforced with $\frac{3}{8}$-in. square corrugated bars, which have their ends hooked over the lowest reinforcing ring. Vertical $\frac{5}{8}$-in. square bars, spaced 3 ft. on centers, were used as vertical distributors. Each reinforcing ring is made up of six sections lapped 30 in. and wired. The rings were also wired to the vertical reinforcement at every intersection.

The forms consisted on the inside of vertical sheathing extending the full height of the reservoir, and of horizontal sheathing on the outside. The thickness of the bottom lining varies from 3 in. to 6 in., so arranged as to offer better drainage than was obtained in the old tank.

The reservoir was completed on October 12, 1911, and filled for the first time to its full depth on November 11, 1911. No leaks whatever have thus far appeared. The only precaution to render the reservoir water-tight other than that of using a fairly wet concrete, which was mixed in the proportion of one part of cement to two parts of sand and four parts of $\frac{3}{4}$-in. broken trap rock,

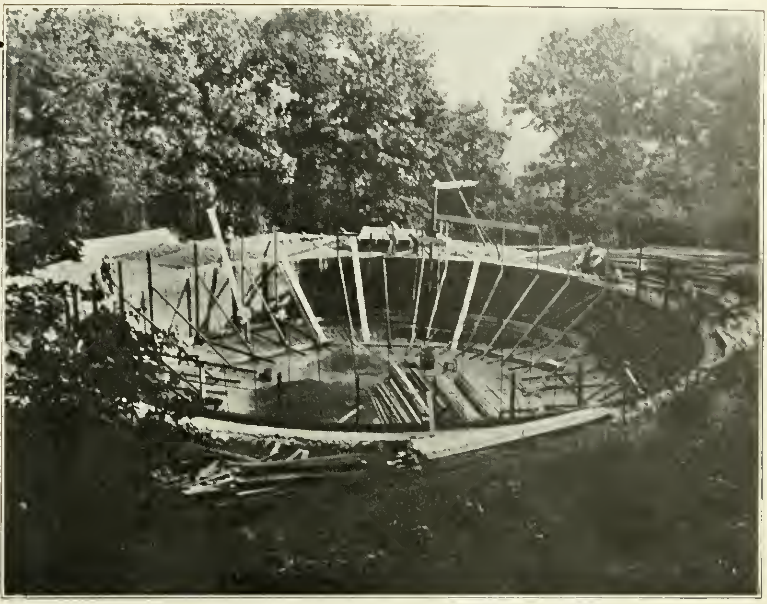

FIG. 1.
PLACING STEEL, SEPTEMBER 20, 1911. RESERVOIR AT SUFFERN, N. Y.

FIG. 2.
FINISHED RESERVOIR, NOVEMBER 11, 1911. ALL EXPOSED WORK NEW CONSTRUCTION.

was to wash the inside of the tank with a semi-liquid Portland cement.

An increase in the storage capacity of 294 000 gal. was obtained at a cost of $2 500, which was the contract price for this work. The location of the reservoir on a steep mountain slope about 180 ft. above the street level added considerable to the cost of hauling the structural material to the site, and, consequently, to the contract price.

SOME WATER SUPPLY PROBLEMS ENCOUNTERED IN THE SEMI-ARID REGIONS OF THE UNITED STATES.

BY CLARENCE GOLDSMITH, ASSISTANT ENGINEER, HIGH PRESSURE FIRE SERVICE, PUBLIC WORKS DEPARTMENT, BOSTON, MASS.

[Read March 13, 1912.]

After the serious troubles which the local members of the Association have undergone during the past six weeks, due to the exceptional depth to which the frost has penetrated, it may be somewhat of a consolation to them to have their minds refreshed by a brief enumeration of some of the difficulties along other lines which are encountered by their co-workers in the semi-arid regions of the United States.

The cities of Los Angeles, Cal., Butte, Mont., and Denver and Colorado Springs, both of Colorado, have been selected to illustrate the problems which present themselves to a water-works engineer in a locality where the yearly rainfall is small. The mean yearly rainfall at the above-mentioned cities is less than eighteen inches, while that in New England is slightly over forty-five inches; so it will be clearly seen that the difficulty of developing an adequate supply is much greater than on the North Atlantic coast. A second consideration of almost equal importance in providing an ample supply is the rapid growth of these Western cities, which requires the supply to be developed more rapidly and a larger margin of safety to be maintained than is necessary in the slower-growing Eastern cities.

The city of Los Angeles, supplied by a municipally owned plant, is located a few miles inland from the Pacific coast, and the built-up portion commences just south of the mouth of the San Fernando Valley, the watershed of which comprises 526 sq. miles. The average annual rainfall in the city is 15.93 in., and it increases on the northern slopes of the mountains about the valley to about 22 in. There is practically no precipitation during July and

August, and only 15 per cent. of the annual rainfall occurs in the six summer months. The rainfall is largely absorbed by the vast gravel and débris deposits which line the floor of the valley to a great depth, thus forming a large subterranean lake which appears as the Los Angeles River near the outlet of the valley. This perennial stream of great constancy has an average annual stream flow of from 29 000 000 to 35 000 000 gal. per day. The readings upon which the above figures are based are taken at the hours of greatest transpiration, for it is observed that the flow is some 2 000 000 gal. less when the vegetation is subject to the heat of midday. The total amount which can be derived from all sources of the supply for short periods of time is about 59 000 000 gal. per day.

The city has acquired the exclusive rights to all water, both surface and subsurface, of the entire watershed to the southern city limits. The upper valley was until recent years one of the most productive areas in the state of California, but the courts forbade any pumping of water for irrigation purposes within its confines, basing its decision on the fact that water required for municipal purposes produced the greatest good for the largest number of people. Thereupon agricultural activities practically ceased.

Water is withdrawn at seven points so distributed as to intercept the entire flow; four are within the valley, one at its mouth, and two within the city. Of the first four, the Main Supply diversion is located eight miles northwest of the city, where the stream flow is diverted by a low timber and gravel dam into a concrete conduit about five miles long, which leads to Silver Lake, a distributing reservoir. The greater portion of this conduit was only covered to the spring line until about two years ago, but it never showed any signs of expansion or contraction cracks, although exposed to the heat of the Southern California sun. The estimated minimum supply from this source is 13 000 000 gal. per day. The river disappears in the coarse gravel deposits immediately below the Main Supply diversion, and the subsurface flow is intercepted by six 10-in. wells from 160 to 239 ft. deep. Water ordinarily stands 5 ft. below the surface of the ground, and when the wells are being pumped by an air lift, at the rate of 4 000 000 gal.

per day, into the main supply conduit, during the summer months, the water plane is lowered 25 ft.

At the Crystal Springs diversion, one and a half miles below the Main Supply diversion, the river again appears on the surface and its flow is diverted by a low brush and gravel dam, at the rate of 12 000 000 gal. per day, into the Low Gravity conduit, which extends about five miles to Buena Vista reservoir, and has branches leading to Bellevue reservoir and to the main supply conduit. This supply is augmented by two lines of percolation pipes and an infiltration gallery which extends across the flood plain of the river, and in addition there are six 12-in. wells which can be pumped by air into the conduit line during periods of maximum consumption. The total available supply at this diversion is 23 000 000 gal. per day.

Three miles below this latter diversion there are five 12-in. wells which can furnish about 4 500 000 gal. per day. Ordinarily water stands 10 ft. below the surface, and when being raised by a centrifugal pump into the Low Gravity conduit the water plane is lowered 15 ft.

At the point where the river emerges from the valley, the latter is very narrow and a ledge extends across its bed, between the hills on either side, very near the surface, thus forming a submerged dam which maintains the water plane in the valley. Across these narrows a tunnel, 97 ft. below the bed of the river, extends through solid rock 2 100 ft., and from the surface of the ground are driven nine wells, with slotted casings 12 to 16 in. in diameter, through the ledge into the tunnel, thus intercepting all the underground flow from the valley. About 6 000 000 gal. can be pumped from this source during periods of maximum consumption. From two well fields in the city, containing eight 12-in. wells, 8 000 000 gal. can be raised and pumped into the distribution system when the other supplies are insufficient.

The above-mentioned source of supply was the only one that was available without the expenditure of a large sum, and any development of importance would require several years to render it available. Therefore, the Water Department was compelled to adopt strenuous means in 1905 to conserve the present supply until an ample one could be developed. The growth of the city has been

phenomenal. The population in 1900 was 102 479, and in 1910, 319 198, showing an increase of 211.5 per cent. in ten years, and a prospect of a like future growth seemed probable, but it necessarily depends upon ample water supply. In 1905, with a population of 225 000, the average daily consumption was 34 000 000 gal., or a per capita of 151 gal. with 8 800 meters in service, and in 1909, with a population of 300 000, 36 000 000 gal., or a per capita consumption of 120 gal. with 32 700 meters in service.

From the above it will be seen that the population increased 75 000, while the average daily consumption increased only 2 000 000 gal., and practically all the saving can be attributed to the judicious installation of meters and their proper maintenance. Here is a point which should not be slighted and which can be exemplified by this city perhaps better than by any other. The full benefits and best results of the meter cannot be attained without constant attention to their upkeep, and the compiling of accurate records in order to determine the types and makes best adapted to the particular service. The meter and service department is well organized and may well serve as a pattern to any city which is undertaking the general installation of meters.

The question of irrigation during the periods of maximum consumption is of primary importance, and much study has been given to this subject by the officials. One thing has been clearly demonstrated, and that is that the most luxuriant and healthy verdure is not grown on ground which receives the greatest amount of irrigation, but rather that which has received the least, provided it has been intelligently applied. Much depends upon the time of day at which the water is applied, but in general it is safe to say that for the dwelling-house lawn an application divided into two periods, one of thirty minutes in the early morning, and one of thirty minutes in the late evening, produces excellent results. It is to be hoped that more complete experiments can be conducted along these lines, and that the consumers may be educated so that they may be able to produce the maximum results with the minimum amounts of water applied. That this will probably come about within a few years seems certain, for the larger irrigation projects in the West are devoting much time to a study of this phase of the question.

In 1905 the citizens of the city, realizing keenly that the future of the city depended upon an adequate water supply, voted to proceed with a construction necessary to bring water from the Owens Valley to the city. The work entailed by this project is now well under way, and the city will probably enjoy the benefits of an ample supply in 1913. The intake of the Owens River is located 37 miles above Owens Lake, about 258 miles north of the city. The watershed tributary to the river has an area of 2 800 sq. miles, and contains twenty-four mountain peaks covered with perpetual snow, thus insuring an unfailing supply which will be at its maximum during the summer months when the largest amounts of water are used in the city. The water will be brought from the intake at elevation 3 812, through 226 miles of conduit, siphons, flumes, and tunnels, 7½ miles of reservoir, and 12½ miles of natural watercourse, to the San Fernando storage reservoirs, elevation 1 130, which will be constructed 18 miles northwest of the city at the head of the San Fernando Valley. The carrying capacity of the conduit will be 280 000 000 gal. daily, and five equalizing storage reservoirs will be located along the route to insure the continuity of the supply, and several power stations will be erected along the route of the conduit to take advantage of the rapid drops in elevation which occur at several places. At the time of the inception of this project it was one of the largest in reference to the distances involved which had ever been undertaken, and when one recalls the relatively small size of the city, all credit should be given to the engineers and the citizens for attempting the consummation of such a project, which involved such an enormous expenditure.

It may be well to stop here and consider the activities of the water department for the period of the previous seven years. The construction of the new supply works has been pushed as rapidly as circumstances would permit; at times over six thousand men have been employed. The per capita consumption has been reduced by a careful maintenance of the distribution system and the installation of about six thousand meters per annum, and the works within the city have been extended by the laying of about thirty-five miles of main pipe and the installation of 4 100 services each year, all of which has been accomplished with a comparatively

small force due to the team work of the employees, which is facilitated by the excellent organization.

The city of Butte, Mont., having a population of about 40 000, lies three miles west of the Continental Divide, and the elevations within the city range from 5 425 to 5 900. Owing to its location at such an elevation there are no large watersheds that are available to furnish an adequate gravity supply. The mean annual rainfall is 15.17 in., with an occasional minimum of 10.29 in. This city has not had an exceptionally rapid growth of population, having increased only 30 per cent. since 1900, but is of special interest from the viewpoint of supply, due to its peculiar location.

The Butte Water Company, operating under a perpetual franchise, furnishes entire supply from five watersheds, sparsely to densely wooded, and uninhabited, which will be briefly described. Basin Creek, which lies south of the city, contains two storage reservoirs, one of which, formed by a masonry dam 250 ft. long and 60 ft. high, at elevation 5 860, has a capacity of 189 000 000 gal.; and the other, about $1\frac{1}{4}$ miles further up the creek, formed by a timber-crib earth-filled dam, 330 ft. long and 40 ft. high, with a concrete core wall, has a capacity of 64 000 000 gal., at elevation 6 199. The run-off of the watershed is supplemented by the headwaters of Fish Creek, which is intercepted and brought across the Divide in a wooden flume about 7 miles long. This supply feeds the low service through a supply main about 12 miles in length, three fourths of which is 24-in. wood stave pipe, the remainder being 20-in. kalameined pipe. The line will carry about 6 000 000 gal. per day.

A condition which was observed on this watershed may be of interest. The bottom of the lower reservoir was carefully stripped before it was filled, and the surface consists of fine clean quartz sand, while no work was done on the upper reservoir, and the original leaf mold and stumps were covered when it was flowed. In the upper reservoir there is practically no trace of algæ growth, while in the lower reservoir, with its clean bottom, this growth becomes extremely troublesome during certain seasons of the year.

The second and more important source of supply is that of the Big Hole River, which drains a watershed on the eastern slope of

the Rocky Mountains, extending southwest to the Bitter Root Mountains. The maximum observed stream flow is 90 000 000 gal. At a pumping station located 25 miles southwest of the city the water is raised from the river at elevation 6 393, against a head of 850 ft., to a masonry standpipe through a riveted steel pipe. The two Nordberg pumps are of very heavy construction to work against this high head; the plungers are $11\frac{1}{4}$ in. in diameter and the rods and tail rods are 7 in. in diameter. From the standpipe the water flows by gravity about 8 miles to the South Fork Reservoir, which is located in the South Fork of Divide Creek, about 18 miles southwest of the city, and formed by an earthen dam with a concrete core wall. The capacity is 13 500 000 gal. The run-off of the watershed above the reservoir contributes to this supply on an average about 1 000 000 gal. per day. Water from this reservoir flows by gravity to a distributing reservoir within the city, at elevation 5 960, which supplies an intermediate service. The supply line, 18.5 miles long, is of particular interest owing to the method of its construction, which enables wood-stave pipe to be used in a large portion of the line, which only for special features would be under an excessive head. These devices consist of four concrete regulating chambers, each divided into two sections by a concrete weir. In the lower of these sections a float is placed which controls a valve on the pipe entering the upper section, so that when it is desired to curtail the supply coming to the reservoir within the city, a gate is closed immediately outside the embankment, and the water backs up successively in the four regulating chambers, each of which throttles the supply entering it without producing any greater head on the individual sections of the wood stave line than is due to the difference in elevations of the successive weirs.

The fifth source of supply consists of two impounding reservoirs in Yankee Doodle Creek, about $7\frac{1}{2}$ miles northwest of the city, and at the present time it is estimated that this supply can furnish about 3 000 000 gal. per day. The distribution system within the city is very difficult to maintain, as the mines have been excavated under a great portion of it, and the timber bracing is continually settling. Kalameined pipe, a patented article of wrought iron or steel, with a special metallic coating, joined by sleeves with

lead joints, is used exclusively, as failures are portended by small leaks rather than by sudden ruptures, as would be the case with cast-iron pipe. As an example of the rapid settlement which has taken place, a 6-in. line laid in a tunnel may be cited. This line is connected through elbows at either end, and about once a year 2 ft. of pipe has to be cut out of the line.

The city of Denver is located on either side of the South Platte River, about 15 miles from the eastern foothills of the Rocky Mountains. Its surface is generally undulating, ranging from elevation 5 134 to 5 482. The population in 1900 was 133 859, and in 1910, 213 381, showing a gain of 59.4 per cent. in the last ten years. The mean yearly rainfall averages about 14 in., with a minimum of about 8.5 in., about 64 per cent. of which occurs between April and August. The yearly evaporation is about 69 in., — practically double that which obtains in Boston. The works which supply the city are owned by the Denver Union Water Company, which owns and controls practically all the water rights which are available for furnishing domestic supply to the city.

The South Platte River furnishes the supply from its surface and subsurface flow at two points outside and one within the city. The flow from a small creek is diverted into a distributing reservoir by infiltration, and that from Bear Creek is stored in one of the storage reservoirs. The river above the city drains an area of 3 910 sq. miles, three fourths of which is of granitic formation and generally sparsely wooded and mountainous, and the remainder prairie land below the foothills.

The precipitation in the mountains is mostly snow which accumulates in the winter months and melts during the months of May and June, producing a high-water period of less than two months' duration, while the low-water period extends over the remainder of the year, during which period the stream flow frequently falls below 20 000 000 gal. per day.

The prairie land when irrigated is extremely productive, so it is not surprising that the stream flow is over-appropriated by the ranch owners and the water company.

The only means to enable a greater amount to be available was to construct a storage reservoir in the watershed; therefore, the

Cheesman reservoir was completed in 1904 on the south fork of the South Platte River, 50 miles south of the city. This storage reservoir is formed by a massive stone masonry dam in a narrow gorge. It is 708 ft. long, 176 ft. thick at the bottom, and 18 ft. thick at the top, and has a maximum height from the stream bed to the top of the dam of 236 ft., a capacity of 25 760 000 000 gal., and an area of 874 acres, at elevation 6 836. The construction of the dam required 80 000 barrels of cement, which was hauled by teams of sixes a distance of 23 miles over a mountain road, and the stone, a gray granite, was quarried within one-half mile of the dam site. The stones are of a uniform thickness of 2 ft., and the mortar joint is 1 in. thick. The masonry work was so well executed that when water is flowing over the spillway, which is located 200 ft. north of the dam in a depression between two mountains, there is no trace of leakage or even sweating on the downstream face of the dam. Water is withdrawn through tunnels driven through the granite mountain north of the dam. Three tunnel entrances at different elevations are controlled by hydraulically operated valves, access to which is provided through man-way tunnels. During the irrigation season, in addition to the water withdrawn for the domestic supply, as much water as is entering in the streams at the upper end of the reservoir must be returned to the river below the dam to take care of the irrigation rights.

This water is carried in the stream bed for about 30 miles, where that portion used for domestic supply is diverted at the Platte Cañon head works into either the Platte Cañon reservoir, or to Marston Lake, through a conduit line. Platte Cañon reservoir is about two miles below the head works, and forms a sedimentation basin of 300 000 000 gal. capacity from which water is passed through slow sand filters having an area of $10\frac{1}{2}$ acres, with a daily capacity of 35 000 000 gal. Water may also be applied to these beds from two small settling basins which are fed directly from the stream.

The supply lines of the system are of exceptional interest. All are continuous wood-stave pipe, are well cross-connected, and the flow through each is recorded by a Venturi meter. The oldest of the longer lines was installed in 1890, and has a length of about 18 miles, in which length there is 44 ft. fall, and the line shows a

carrying capacity, by meter measurement, of 8 000 000 gal. per day. There are three other lines of similar length, a 30- and 34-in. line having a capacity of 13 000 000 gal., a 40-in. line having a capacity of 23 000 000 gal., and a 44- and 48-in. line having a capacity of 25 000 000 gal. The continuous wood stave pipe has proved itself well adapted for conduit lines, as the cost of installation is much less than that of steel or of cast iron, not only due to the lower cost of the material, but also to the greater ease with which it can be transported, particularly to points difficult of access. The maintenance is moderate, and in case of failure, repairs can be made much more expeditiously than either on steel or cast iron; and another reason of almost equal importance is that the coefficient of its carrying capacity remains constant. In applying the Hazen-Williams formula one is perfectly safe in using a coefficient of 125 in making calculations, and there are several lines which show coefficients as high as 140. In different parts of the West various woods are used to make the staves — redwood, Oregon fir, and Texas long-leaf pine. The redwood is somewhat too soft to take the tension of the bands without allowing them to cut in too deeply, but the two latter-named woods have proved very satisfactory, and practically all of the Denver lines are made of Oregon fir pine. The wood in the line when properly installed, that is, when all points are below the hydraulic gradient, and suitable air valves are provided on its summits, has a very long life, but the bands, which are the first to fail, have a life of only about twenty-five years, depending upon the quality of the original material, their coating, the care with which they were installed, and the nature of the soil. Experience shows that a rolled thread is preferable to a machine-cut thread, and when they are used it is unnecessary to upset the thread end of the rods in order to secure their full strength.

The remaining supplies do not present any features particularly worthy of note, both being infiltration galleries, one of which delivers by gravity and the other by pumps. All water is filtered, either naturally by infiltration or artificially by either slow sand or mechanical filters, before it enters the distribution system.

The average daily consumption in 1910 was 49 200 000 gal., which, with an estimated population of 213 000, gives a

per capita consumption of 229 gal., and the maximum daily consumption is about 70 000 000 gal. No particular effort has been made to reduce the consumption, and there are only about 400 meters in service. Upon first thought it would not appear to be an economic operation of the works to foster so large a consumption, as it has required the installation and maintenance of numerous large conduit lines, but if this water were not used for domestic supply the present water rights would be lost, and it would be well-nigh impossible to secure additional rights which would be required as the city grows. Now any large increase in population can be easily served by adopting measures to reduce the per capita consumption.

The position of the Denver Union Water Company is unique, for although it has been in litigation with the city since the expiration of its franchise in 1910, and prior to that time had many disagreements with the city, it continues to develop the works and expends more than half a million dollars each year, and it always has maintained a system, the efficiency of which is equalled by few cities whose works are either privately or municipally owned.

Colorado Springs is located about 75 miles south of Denver, and has a population of about 30 000. The city lies at practically the same elevation as Denver, and enjoys the same climatic conditions. The supply is derived from a series of watersheds which comprise the southeastern slope of Pike's Peak. Their combined area is 29.57 sq. miles, and that which does not lie above the timber line is from moderately to sparsely wooded. The rainfall on the watersheds varies from about 15 to 30 in., and the snowfall from 97 to about 200 in., but the run-off from the latter is very uncertain, for at these high altitudes it is not uncommon for practically all the snow to disappear without contributing more than a very small amount to the run-off. There are six storage reservoirs which have a combined capacity of 2 194 000 000 gal. Two of these are above timber line, and the higher, at elevation 12 099, is the highest storage reservoir in the world. From the lower storage reservoir water is discharged into Ruxton Creek, and at a point $1\frac{1}{2}$ miles below is diverted into a 16-in. main by a low timber-crib dam at an elevation of 9 241. This line extends for about one-half mile

to a reinforced concrete equalizing reservoir from which a 20-in. riveted steel pipe, having a capacity of 17 000 000 gal. per day, follows the contour of the mountains in a gradually descending grade for the first part of its course, and then abruptly descends to a power house located in Manitou, where an available head of 2 400 ft. is used to operate Pelton wheels which discharge into a settling basin, from which point three lines, an 8-in., 16-in., and 24-in., convey water into the distributing reservoirs in the city. The average daily consumption in 1910 was about 8 000 000 gal., which shows a per capita consumption of 232 gal. The maximum occurs during the summer months, and 13 000 000 gal. was used in July, 1910.

DISCUSSION.

THE PRESIDENT. Mr. Goldsmith, I was interested in what you said about the two reservoirs at Butte, Mont., one of which had been stripped and the other not, and one containing bad water and the other good water; have you any theory upon which to explain that?

MR. GOLDSMITH. No, I have not, and the superintendent of the works says that it is beyond him. He was building a reservoir on Yankee Doodle Creek when I was there, and he was taking no chances but was stripping the site. I saw the water myself, and in the upper reservoir it was as clear as could be, while in the lower reservoir, which has this fine quartz bottom, it was simply green with algæ. Mr. Carroll is probably one of the most able water-works superintendents in the country. He is an Annapolis man, a thorough-going engineer in every respect, but he has been unable to solve the problem.

THE PRESIDENT. Do I understand that the water is drawn from the upper reservoir to the lower?

MR. GOLDSMITH. It flows down a brook for about three quarters of a mile.

MR. RICHARD A. HALE.* I would like to inquire if the life of the wood pipe and the bands, etc., does not depend on the material in which the pipe is imbedded? The

* Principal Assistant Engineer, the Essex Company, Lawrence, Mass.

reason I ask is that I have recently taken out in Lawrence a wooden penstock which has been in for forty-six years. It was composed of white pine, surrounded by iron bands. The material in which it lay is not clay puddle, but ordinary material, something like river silt, possibly, puddled. There is no indication whatever of decay in the wood, and a section across the iron bands shows them to be as bright as they were on the day on which they were put in. There is apparently no reduction whatever in the section, and every part, the wood and iron, seems to be exceedingly well preserved. There was, of course, no exposure to the air, and I was wondering whether the life of this kind of pipe mentioned by Mr. Goldsmith did not depend very much on the material in which the pipe is laid and upon whether or not it is exposed to air and water and is alternately wet and dry.

Mr. Goldsmith. I believe I covered that point. I said that among other things the life of the pipe depends upon the material, the soil, in which it is laid. I would say that the failure of the bands on wood stave pipe up to the present time has practically always been in the threads, and the rolled thread had not been used long enough to have it determined where the failure is hereafter going to be. A few staves in a line would go bad, and when they took those portions out and moved the nuts on the bands, they found that the thread was practically all gone.

Another thing that has been developed by the Denver Union Water Company has been in connection with the putting on of the new bands. They used to be made in a complete circle, and in wiggling them under the pipe a little of the coating would be torn off. Now they are making the bands in two sections, held together by a malleable iron clamp or saddle. That method of construction not only enables them to get the bands around the pipe without injuring the coating, but also to get a great deal better tension on the pipe. They like to lay the pipe in the winter, for the staves are dry, and when there is a little frost on them they drive home better than they do in warmer weather.

The President. Have you any theory or any reason upon which you can explain why the rate per capita at Los Angeles should be so high?

Mr. Goldsmith. It is on account of the rainfall. Only 15

per cent. of the rainfall, the total amount of which is very small anyway, is during the summer months, and there is practically none during July and August. Now Los Angeles is a garden city, you may say. When I was looking up the question of irrigation I found two estates, each of which occupied half a block. The meter on one estate showed that during the year they had used water enough, including what was used for household purposes, the exact amount of which of course could not be determined, to have covered the land to a depth of 14 ft., and, in the case of the other estate, to have covered it to a depth of 7 ft. It is a city of homes. Practically every one owns a little home and has a little garden, and nothing will grow in it without irrigation. That probably accounts for the high rate.

Mr. G. C. Whipple (*by letter*). The writer has been very much interested in reading Mr. Goldsmith's paper, and especially that part of it relating to the growth of algæ in the reservoirs of the Butte Water Company. The fact that algæ have given trouble in the reservoir that was carefully stripped before it was filled, and have not given trouble in the upper reservoir, which was not stripped, is in line with numerous instances which have come to his attention during recent years. It is quite evident that our ideas in regard to the control of algæ growths in reservoirs must be modified by these recent observations, and stripping cannot any longer be regarded as a general panacea for this trouble. It is evident that there are many conditions other than that of providing a supply of organic food material that are involved in the problem. Therefore, if the author could give us further information in regard to the nature of the algal growths and the physical and topographical conditions of the reservoirs, he would be adding to the knowledge that must be accumulated before an adequate theory as to the cause and control of algæ growths can be advanced.

Since the early work on the subject of algæ growths was undertaken by members of this Association twenty years and more ago, comparatively few investigations in this country have been published and the science of limnology has been allowed to wane. Meantime, however, some extensive investigations have been made in Europe, especially in Scotland, where questions of temperature, currents, etc., have been investigated in detail. References to this

foreign literature may be found in the files of the *Internationale Revue der Gesamten Hydrobiologie und Hydrographie*, which has been published since May, 1908. In this country the most important references to the subject are the report of Messrs. Allen Hazen and George W. Fuller on "The Relation of Reservoir Stripping to the Improvement in Quality of Water," published in the Annual Report of the Board of Water Supply, City of New York, 1907, and the monograph of Dr. Edward A. Birge and Chancey A. Juday on "The Dissolved Gases of the Water and their Biological Significance," published in Bulletin XXII of the Wisconsin Geological and Natural History Survey.

The writer hopes to review all of this literature during the near future, and thus make it available to the members of the Association, hoping that it will stimulate anew the interest in the general subject of limnology.

METHODS OF THAWING FROZEN SERVICE PIPES, AND DISTRIBUTING THE COST THEREOF.

TOPICAL DISCUSSION.

[*March 13, 1912.*]

Mr. J. J. Prindiville.* Mr. President, there is one question I would like to bring up here this afternoon which is of vital interest to the smaller departments, and that is, how to treat the services entering from the street mains to the houses of the consumers.

This last winter, which has probably been as cold as any winter in the past twenty-five years, we have had a great deal of difficulty from freezing. There has been very little trouble with the mains, but there have been from 150 to 200 services frozen on private grounds. Those services are paid for, when they are put in, by the owners, and when they are frozen the owners call on the department to thaw them out. Now the question is as to whether the expense of doing that should not be borne by the owners rather than by the department. The reply to that is that the services were put in, in almost every case, under the direction of the department, and the owners say that under those circumstances, as the department assumed the responsibility for putting them in, it should pay for the expense of thawing them out. This becomes quite a serious question when we have a winter like the past one, and so I would like to bring the matter up for discussion to see if we cannot get some information as to the best way to treat the subject and learn the opinions of the members as to whether the department or the owners of the services should pay the charge for thawing them out. Another question is as to the best method in use for thawing out these service pipes.

The President. I would say that we have had a great many frozen services in Worcester this year, and they were laid by the Water Department. We have taken the attitude that where a

* Member and Secretary Water Commissioners, Framingham, Mass.

service was frozen in the street the city would assume the responsibility, but if the freezing clearly started in the cellar we would charge the expense of thawing to the consumer. That seems to be perfectly fair.

Mr. Prindiville. What would you do if the house was 100 ft. from the street and the service was frozen under the lawn?

The President. I should hold the consumer responsible, if the freezing was on his premises. Oftentimes services are put in when the grade of the lawn has not been established, and in those cases the Water Department uses the best information it has, and if it turns out that the owners do not fill in as much as they had planned to do, so that the frost gets down and the pipe freezes, we do not think the department should be held responsible. But if the grade is established, and the department puts the service in, we think we are morally bound to take care of it, unless the freezing begins in the cellar and works out through the cellar wall. Then we think that the consumer should pay for thawing the pipe out.

Mr. Edwin C. Brooks.* I would like to ask how you determine that it starts in the cellar and works out.

The President. It isn't difficult to determine that in a good many cases. Sometimes when we start thawing we will get the water through before we have gone more than two or three feet beyond the wall.

Mr. Brooks. The stand that we have taken in Cambridge has been that we were to furnish water to the sidewalk cock, and that the owner is responsible for what happens from the sidewalk cock to the house. I wish some of you gentlemen who have put on goosenecks and some of those contraptions that are supposed to take up the expansion and contraction of service pipes had to wiggle the thawing coil around through some of them. I think it would convince you that, although they might have advantages, they certainly add to our difficulties. And, another thing. Why can't there be some uniform method of putting services into houses? Why can't they come in above the cellar bottom, and not go into a little well, as they often do, and then run back under the concrete floor of the cellar? It is very difficult to get a coil into the pipe

* Superintendent of Water Works, Cambridge, Mass.

under such conditions. It seems to me that before we live a great many years longer we ought to adopt some uniform method of putting in supplies which will provide that the supply shall enter the cellar two or three inches or more above the finished cellar bottom, and that the stop and waste valve shall be accessible. It would add very much to the ease of thawing out supplies if something of that sort could be adopted. Then there is another thing: to have ample water-ways in sidewalk cocks and in corporation cocks adds very much to the peace of mind of the person who is trying to get a coil through, instead of having one of these little oblong openings which the coil will scarcely go through. There are a good many of these little details which, if they were attended to, would add very much to our ease in getting along, and if we are to have many winters like the past one, it would seem as though they would have to be provided for.

Mr. Frank A. McInnes.* With approximately 100 000 services in Boston, we have had about 200 frozen. I have a list of deposit slips, and have to settle whether we shall pay the money back or keep it. In the majority of the cases it is the same old problem as to where the freezing started, — whether on the premises or in the street.

With regard to the method of thawing the pipes out, I am satisfied that there is one best way, and that is to have your own electric plant, consisting of motor and generator of say 25-kilowatt capacity, which you can put on an electric truck or on a wagon and move from place to place. We have lost a large amount of time both with the A.C. and D.C. current in getting connections, grounds, etc., and have decided that we must have our own outfit. I have talked with some of the water-works supply men and have asked them to get up something and put it on the market before next winter.

The next best thing to electricity is steam under pressure, live steam carried right from the boiler into the pipe.

Mr. Brooks. I would suggest a small portable tubular boiler operated by either gasolene or kerosene under pressure to boil the water that you use in your coils, so that when you start thawing out you will be sure to have plenty of hot water. In many of

* Division Engineer, Sewer and Water Division, Boston, Mass.

the poorer districts, when the supplies are frozen, a man will have to go from house to house to get a pail of hot water. There are but few hot water boilers in the vicinity. He may find a teakettle of water on the stove, but the woman will want it herself, and then the man will have to run to the nearest engine house or schoolhouse or some place of that kind with the hope of getting some water there. It is much more satisfactory to have a small boiler from which you can put a steam jet into your pail and keep the water boiling hot, so it can be used in the coil when it is hot instead of lukewarm.

There is another idea that I have had in mind, and that is whether it is not possible for us to use the spiral steel pipe that is rolled in a spiral and locked together. They use it for tube blowers, and I understand it is made in sizes as small as $\frac{3}{8}$ in. It seems to me that would stand rough usage and not be liable to be pulled apart in pulling it out of the services, and would be very much better than the ordinary block tin coil that we are using now.

Mr. McInnes. In Boston we use small boilers delivering live steam under 4 or 5 lb. pressure through a $\frac{3}{8}$-in. lead pipe into a service or through a $\frac{5}{8}$-in. pipe into a larger pipe.

Mr. Prindiville. The question which troubles me still remains, Mr. President, and that is, who is to pay? In most departments the rules provide that the services must be put in subject to the approval of the department, — either put in by the department or subject to the approval of the department. Now if they freeze, how are you going to decide, as has been said, whether the freezing begins at the street end or at the house end? The pipes are frozen and the owners come to you for relief. At one time this winter we had so many of such cases that it took us two weeks to get around. In a number of instances there was severe sickness in the houses, and it was a very great hardship not to be able to use the waterclosets and bath-rooms.

Now suppose you say to the owner that he has got to pay to have his service thawed out and that you will require a deposit. The owner refuses to pay, on the ground that you have got to furnish him with water. You are already charging him for it, and you have got to furnish it to him, he claims, and you are not giving it

to him. It seems to me that there is quite a big question for us to consider. It may be a legal question as to whether you can take the ground that you will not thaw the service out and yet will charge the owner for water. In order to get some light on this subject, and the matter is one which is of particular importance to small departments, I would suggest that a committee of three or five, whichever number you see fit, be appointed to take this matter up and make a study of it and recommend to the Association the best method to adopt as to who must pay the bills for thawing frozen services. It does not seem right, in one aspect of it, for us to stand by and say we will not thaw them out, and yet at the same time charge a minimum rate for the water.

THE PRESIDENT. Our way in Worcester would be to thaw out the service and then to thresh out afterwards the question of who shall pay for it. Get the water running in the first place, for you will then be on the safe side, and take up the question of payment later. I think it would be very difficult to establish any uniform practice for the different cities and towns. It seems to me the question would be very largely a local one.

MR. PRINDIVILLE. If you eliminate the charge in one case, you have got to do it in all cases.

THE PRESIDENT. Under the same conditions, yes. You have got to be consistent. I have learned that you cannot safely make any exceptions.

MR. FRANK C. KIMBALL.* To answer the gentlemen's question specifically, it seems to me that it must depend entirely upon the conditions under which service pipes are laid in the particular place. Some departments assume the laying of the pipes to the cellar wall, charging a certain price per foot, the cost, or whatever it may be, and laying them as they see fit, using the kind of pipe they may choose and at such depth as in their opinion is necessary. I think in such a case as that there is hardly any question but what the expense of thawing the pipe should be borne by the department. On the other hand, some departments run merely to the curb or to the street line, and it is for the owner to get a plumber and bring the water into the house. Even though that be done subject to the approval of the department, I think in such a case it would

* General Manager, Commonwealth Water and Light Company, Summit, N. J

be for the householder to pay the expense of thawing out the pipe, because, while it is subject to the department's approval, it is not beyond the province of the property owner or his plumber to do a better job than the department requires, although they seldom do it. So, as I say, in all cases I think it is the way the rules or regulations of the department read which will largely govern as to whether the department or the property owner pays the bill. As to drawing an exact line where the freezing begins, whether in the cellar or at the main or at the property line, you cannot always do it.

Mr. Walter H. Richards.* Mr. President, I agree with Mr. Kimball. I think if the city lays the pipe across a man's lawn into his house, the city should be at the expense of thawing it out in case it freezes, for the city assumes responsibility by laying it.

To determine just where the freezing starts is very difficult. I think it is a very rare case in which you can do it with absolute certainty. I have one case in mind where the pipe froze solid right out to the curbstone and the service did not freeze at all, although it was not laid any deeper than the pipe to the sidewalk was.

Mr. Arthur F. Ballou.† We began by using live steam for thawing pipes. The city of Woonsocket is responsible for the pipe to the curb line.

We investigate each case of freezing that is reported to us. If we get water at the curb we at once shut it off so as to drain the private part of the pipe and prevent the freezing from working back into our part of the pipe. If the service is off a big main, one of the principal arteries of the city, we put in steam and thaw out the ground so as to protect the main pipe.

The requests to be thawed out became so numerous that we had to begin to use electricity because we could do the work so much quicker. We thawed the consumer's part of the pipe and ours at the same time, and we bore the expense, if both parts of the pipe were frozen. But where we had water at the curb we notified the consumer that we should expect him to pay us the cost,

* Engineer and Superintendent, Water and Sewer Department, New London, Conn.
† Superintendent of Water Works, Woonsocket, R. I.

and nobody demurred at that. They seemed to expect to pay it.

We have had quite a lot of trouble this past winter. We had over one hundred frozen services, and everybody realized that we were working hard to remedy the conditions, but that we were up against a pretty tough proposition. Perhaps that had something to do with the attitude of the consumers. They treated us very kindly, perhaps differently than they would have if there had only been five or six cases. There was only one man who was dissatisfied, so far as I know, and he had only been taking water about four weeks. He is wiser now, and I think if he had had the water for several years he would have realized the conditions better. Nobody demurred against paying the expense, and of course there were so many pipes frozen that the charges when they are divided are not going to be exorbitant. We did our best to protect our mains and to keep the consumers supplied with water.

I think in Woonsocket we look at the question of the service pipes a little differently from any man who has spoken here to-day. Anybody who applies for permission to make connection with our mains and to take water is given the privilege of making the connection. It is a privilege. We do not guarantee to give uninterrupted service; we cannot do that; and our consumers all take the water under those conditions. We do our best, of course, to keep the water flowing in the mains, but as far as any liability on the part of the city is concerned, we do not admit it. As a general thing, the people accept the service in that spirit. We have been very fortunate, we have not had many interruptions, and nobody ever attempts to be disagreeable. In case a main breaks they realize that we get to work and fix it as soon as possible, and they are perfectly willing to wait, and, of course, they are more so if they have a neighbor on another street who has water.

Mr. McInnes. One way to avoid trouble would be to adopt the method used by the largest city in the country, New York, and that is to have absolutely no responsibility beyond the main. That is the rule in New York City; they have charge of the main pipe and everything else is up to the owner.

Mr. Brooks. I think, Mr. President, that considerable

trouble might be avoided if services were not laid under walks leading up to the houses. It is frequently the case that a service pipe runs under the walk, which is kept shoveled off in the winter time, and, of course, the frost then has a chance to go down much deeper than it does on the lawn, which is covered with snow and where there is a coating of grass.

Mr. Frank E. Fuller. Mr. President, I would like to inquire what the cost of thawing out service pipes by an electric current is?

Mr. McInnes. I can tell you exactly what it cost us this year, but as it was all emergency work the data is really of little value. A great deal of time was lost trying to make connections, in running secondary wires and in waiting; we were actually working but a small part of the time. The entire cost of thawing divided by the actual number of services thawed, including one elevator pipe which took a half a day, amounted closely to $19. The total cost divided by the total number of services we thawed and tried to thaw, loosing a great deal of time on some without actual work, amounted to $14 apiece. With your own outfit, the expense is only a matter of a dollar or two at the outside.

Mr. Brooks. What do you use for power?

Mr. McInnes. With the A. C. current we used a 50-kilowatt transformer and a water rheostat working often without a ground. We got our primary on one side connected and let the ground take care of itself. I want to emphasize the fact that our cost of thawing is absolutely no criterion of what it should cost, because it was emergency work and we let nobody wait.

Mr. Frank E. Winsor.* I do not think that I am qualified to speak on this matter, but as Mr. Fuller has asked the question as to the cost, I might say that in White Plains, N. Y., the Westchester Lighting Company has made a business of thawing out frozen services, of which there have been a great many during the past winter. The rule in force by the water department places the responsibility for the house service entirely upon the householder, and the department has no interest in thawing out service pipes. If such pipes freeze, the householder or owner of the property must arrange for thawing them out. The charge for thawing, where there are no particular complications, was fixed

* Department Engineer, Board of Water Supply, City of New York.

in the early part of the season as $7.50 and was later increased to $10 per service. In Tarrytown, N. Y., the same company has charged $15 per service during the past winter. Special prices have been made for large jobs.

Mr. McInnes. The owner of the outfit which was working for us told me that in the adjoining town of Norwood he thawed twelve services at once, so the expense would naturally be a good deal less than our cost. What we paid is no criterion, for our frozen pipes were isolated, in all parts of the city.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, Mass., March 13, 1912.

President George W. Batchelder in the chair.
The following members and guests were present:

Honorary Member.

Desmond FitzGerald.— 1.

Members.

S. A. Agnew, J. M. Anderson, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, F. D. Berry, A. E. Blackmer, E. C. Brooks, G. A. Carpenter, E. J. Chadbourne, J. C. Chase, J. H. Child, M. F. Collins, John Doyle, E. R. Dyer, E. D. Eldridge, J. W. Ellis, G. T. Evans, A. N. French, F. L. Fuller, M. L. Fuller, A. S. Glover, Clarence Goldsmith, F. H. Gunther, R. A. Hale, F. E. Hall, M. F. Hicks, H. C. Ives, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. Stacy, Morris Knowles, C. F. Knowlton, F. A. McInnes, N. A. McMillen, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, F. L. Northrop, T. A. Peirce, J. J. Prindiville, W. H. Richards, L. C. Robinson, A. L. Sawyer, C. W. Saxe, G. A. Stacy, W. F. Sullivan, J. L. Tighe, E. J. Titcomb, W. H. Vaughn, R. S. Weston, Elbert Wheeler, William Wheeler, F. I. Winslow, G. E. Winslow, F. E. Winsor, H. V. Macksey, T. G. Hazard, Jr. — 63.

Associates.

Builders Iron Foundry, by F. M. Connet; Darling Pump and Manufacturing Company (Limited), by H. H. Davis; Glauber Brass Manufacturing Company, by S. S. Freeman; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey and R. D. Wertz; Norwood Engineering Company, by C. E. Childs; Pratt & Cady Co., by C. E. Pratt and M. J. Kane; Platt Iron Works Company, by F. H. Hayes; Rens-

selaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle; Henry R. Worthington, by Samuel Harrison. — 24.

Guests.

I. P. Wood, inspector, Marlboro, Mass.; Henry C. Page, Arthur E. Tucker, Worcester, Mass.; Robert E. Whittle, Arlington, Mass.; John E. Minos, J. E. Parker, E. F. Hughes, Boston, Mass.; Ivers M. Low, superintendent water works, Weymouth, Mass.; Herbert W. Hunt, Reading, Mass.; Howard V. Allen, water commissioner, East Greenwich, R. I.; D. R. Howard, Woonsocket, R. I.; George E. Stimson, Rochdale, Mass.; W. F. Woodburn, Philadelphia, Pa.; John A. Thompson, A. E. Barrett, Lowell, Mass.; Frank S. Newell, John F. Browning, and John J. Mack, water commissioners, Salem, Mass. — 18.

The records of the last meeting were read by the Secretary and approved.

The Secretary announced that the Executive Committee had this forenoon voted to hold the next annual convention at Washington, D. C., during the third week in September.

Applications for active membership, properly endorsed and recommended by the Executive Committee, were presented from Charles E. Perry, Canajoharie, N. Y., engaged in sewer and water-works construction and design; Philander Betts, Newark, N. J., chief engineer Public Utilities Commission, State of New Jersey; and for associate membership from Francis H. Coffin & Co., Scranton, Pa., general sales agents for hydraulic supplies, particularly machine-made wood stave water pipe.

On motion of Mr. Thomas A. Pierce, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

Mr. Frank C. Kimball, civil and hydraulic engineer, Boston, Mass., read a paper entitled "How the Water Emergency at Worcester, Mass., was Handled in the Summer of 1911, together with a Brief Description of Worcester's Sources of Water Supply." The paper was illustrated by stereopticon views. The President, Mr. Batchelder, spoke briefly upon the subject of the paper.

Mr. F. A. McInnes, for the Committee on Standard Form of Specifications for Cast-Iron Water Pipes and Special Castings, which was requested at the last meeting to consider and report as to the advisability of making some changes in the standard specifications, presented the following report:

Mr. President, — I am sorry that the chairman of our committee is not here, but I have the results of our labors and with your permission I will read the report:

March 13, 1912.

New England Water Works Association:

In 1902 this Association adopted a Standard Form of Specifications for Cast-Iron Water Pipe and Special Castings which has been used during the past ten years by members of the Association and other users of cast-iron pipe throughout the country; in the meantime the American Society for Testing Materials and the American Water Works Association have each adopted standard specifications differing slightly from those of this Association.

While our specifications have well served their purpose, your committee believe that the time has come when certain changes should be made if they are to continue, economically, to make for the best results, and it therefore recommends that they be revised. Your committee realize from past experience that the questions to be considered will undoubtedly entail a large amount of work, involving the making of computations and drawings; it is, therefore, suggested that the matter be placed in the hands of a new committee of five, to be appointed by the President, and that the committee be authorized to expend not exceeding $500 for assistance in the preparation of its report.

Dexter Brackett,
F. F. Forbes,
F. A. McInnes,
Committee.

That is all that the committee has to say on the matter.

On motion of Mr. George A. Stacy, the report of the committee was accepted and its recommendations adopted.

The President subsequently appointed Messrs. Frank A. McInnes, Dexter Brackett, Frank A. Barbour, William R. Conard, and George A. King as members of the committee.

Mr. Clarence Goldsmith, assistant engineer, High Pressure Fire Service, Public Works Department, Boston, Mass., read a paper entitled " Some Water Supply Problems Encountered in the Semi-Arid Regions of the United States," and dealing with the

water supplies of the cities of Los Angeles, Cal.; Butte, Mont.; and Denver and Colorado Springs, Colo. The President and Mr. Richard A. Hale made certain suggestions and asked certain questions which were answered by Mr. Goldsmith.

The President announced that a letter had been sent out to various water departments with a view to obtaining opinions as to the proper depth to which water pipes should be laid in various localities. He said that in Worcester the pipes were laid to the depth of about $4\frac{1}{2}$ ft. to the center of the pipe, and this year the frost had gone down 6 ft.

EXECUTIVE COMMITTEE.

Boston, Mass., March 13, 1912.

Meeting of the Executive Committee of the New England Water Works Association at the rooms of the Association, 715 Tremont Temple, at 11.30 A.M.

Present: President George W. Batchelder, and members Frank A. McInnes, Millard F. Hicks, Morris Knowles, Robert Spurr Weston, George A. Stacy, Lewis M. Bancroft, George A. King, and Willard Kent.

Three applications for membership were received and recommended for admission, namely:

For members: Philander Betts, chief engineer, Public Utility Commission, State of New Jersey, Newark, N. J.; Charles E. Perry, civil engineer, Canajoharie, N. Y.

For associate: Francis H. Coffin & Co., Scranton, Pa.

A communication from Mr. B. N. Simin, civil engineer, of Moscow, Russia, together with notes on and blueprint of fire hydrants, was received and the Secretary was instructed to express to Mr. Simin the appreciation and thanks of the Association for his interest in the matter. The several papers were referred to the Committee on Fire Hydrants.

The President announced the result of the vote of the members of the Executive Committee on place for holding the next Annual Convention to be as follows: viz., Washington, D. C., 5; Phila-

delphia, Pa., 3; New York, 3; and the individual expense of attending convention in the places named to be approximately as follows: Washington, $37.50; Philadelphia, $30, and New York, $30.

On motion of Mr. Bancroft, seconded by Mr. McInnes, it was voted that the next annual convention of the New England Water Works Association be held in the city of Washington, D. C.

Voted, on motion of Mr. Weston, that the date of the next annual convention be Wednesday, Thursday, and Friday of the third week in September.

Voted, on motion of Mr. Knowles, that Mr. King and Mr. Kent be a committee to investigate and report on the expediency of visiting the Cape Cod Canal on the occasion of the June Outing.

Adjourned.

WILLARD KENT, *Secretary*.

New England Water Works Association.

ORGANIZED 1882.

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STATE CONTROL OF THE DESIGN AND CONSTRUCTION OF DAMS AND RESERVOIRS. ACTUAL PRACTICE IN EASTERN CONNECTICUT.

BY CHARLES E. CHANDLER, C.E.

[*Read September 18, 1912.*]

The Connecticut statutes passed in 1878 provide for the repair of unsafe dams as well as for approved design and construction of new dams. This paper is confined to the actual operation of the law in regard to new dams in Eastern Connecticut with which the writer was connected as engineer for the owners or for the state, or of which he had special knowledge.

The essential part of the law so far as this paper is concerned is as follows:

"SECTION 4803. *Approval of Dams.* — Before any person or corporation shall construct a dam or reservoir in a locality where life or property may be endangered through the insufficiency thereof, the plans and specifications for such dam or reservoir shall be submitted to a member of said board of civil engineers, who shall examine the ground where the dam or reservoir is to be built and the plans and specifications therefor; if he approve the same, he shall issue a certificate authorizing the construction of such dam or reservoir. No such dam or reservoir shall be constructed without such approval and certificate.

"SECTION 4804. *Inspection of Work; certificate of approval.* — The engineer under whose authority a dam or reservoir is being constructed shall inspect the work or cause the same to be in-

spected at least three times before completion; and if he shall be satisfied that such dam or reservoir has been built in a substantial and safe manner, in accordance with the plans and specifications approved by him, and is strong and secure, he shall issue a certificate approving the same, which certificate shall be recorded in the office of the town clerk of the town in which such dam or reservoir is located. No such dam or reservoir shall be used until such certificate is obtained and recorded."

All the expense of approval and inspection is borne by the owner of the dam.

The first experience that the writer had with the practical operation of the law was about twenty-three years ago, when he made the plans for a dam for a manufacturer under the specific direction of the local member of the State Board. As engineer he made no surveys, did not see the site and exercised no discretion whatever, and never saw or heard of the dam afterward. Presumably it was built and is standing.

For the second dam the writer made a survey of the ground, but prepared the plans and specifications in accordance with the direction of the State Engineer. The owner at first refused to have grades and lines given for starting the construction work, on the theory that the contractor had agreed to build the dam and the owner had nothing further to do. On the refusal of the contractor to begin the work until lines were given on forms erected by him, the owner caused such lines to be given. The dam was built without other inspection than that given by the State Engineer.

When the reservoir first filled with water the whole spillway section went downstream, leaving the remainder of the dam, which, like the spillway, was of stone masonry, standing unharmed.

It should be remembered that the law does not require the State Engineer to visit a dam more than three times.

Later the dam was rebuilt in accordance with the same plans and specifications, under the constant supervision of an inspector, and it is still standing after more than twenty years has elapsed.

In another case the writer made plans and specifications for a dam for the owner under the direction of the State Engineer and the dam is in good condition at the end of twenty-five years.

In a case coming under his observation plans were approved by the State Engineer, who declined to approve the construction because no spillway was provided. A spillway was added later when its necessity had been demonstrated, fortunately without damage.

In another and very important case that the writer had opportunity to know about, the plans and construction were approved by the State Engineer. A portion of the spillway, about two hundred feet in length, went out on account of an insufficient foundation, and was replaced by a timber construction. The State Engineer took no part in this replacement, deciding that it was "repairs," and that approval of repairs was not required by law.

This State Engineer had a record of at least nine dams, two of which failed in part, and in neither case was the failure due to the plans or specifications. No very serious damage to other than the owners occurred as a result of these failures. The damage to the owners was about $80 000.

In about the year 1891, on the death of the former incumbent, the writer was appointed a member of the Connecticut State Board of Engineers, having supervision of dams and reservoirs.

In regard to small proposed dams, the question as to necessity of state control in specific cases has sometimes arisen. The writer declined to decide these cases. If the owner wished to run the risk of building without approval, the writer saw no reason for objecting. If the owner preferred to be on the safe side and obtain approval, his attitude was unchanged.

When plans and specifications were submitted for approval, the writer first gave attention to the dimensions of the spillway and learned the area of the watershed. If the spillway provision fell much short of that recommended by Fanning, a study was made of the character of the watershed, the capacity of other spillways on the same stream, and the amount of storage on the stream above the point in question, and such information as was available as to floods on the stream in question and nearby streams. In the light of such knowledge a capacity somewhat less than Fanning's was sometimes allowed.

When the capacity of the spillway was decided, it was required that the spillway masonry be of sufficient dimensions to bring the

resultant within the "middle third" of the base with the water at level of top of abutments with no water downstream from the dam.

Other things too numerous to mention were required.

In many and perhaps in the majority of instances the plans were made by competent engineers and the dams built under careful supervision. In such cases the duties of the State Engineer were merely nominal.

In other cases the plans and specifications presented called for dams that were wholly inadequate. In these cases new plans and specifications were made to the acceptance of the State Engineer, sometimes after many conferences.

When competent inspectors were constantly on the work, and the State Engineer had faith in the owner and builder, five visits only were made; the first to examine the site, the last to inspect the finished structure, and three at intermediate times.

In cases where builders and engineers were inexperienced in dam building, and especially when the only engineer employed was also the contractor, more frequent visits were made.

In one case the work was visited two or three times a week while the masonry was in progress.

While the writer has been a member of the State Board, he has had his own plans for dams approved by other members of the State Board whose practice has been substantially like that herein described. On one occasion, the State Engineer required an increased width of embankment.

In one case a water privilege was sold subject to the provision that any dam erected thereon should meet the approval of an engineer employed by the grantor, who was the owner of the adjoining downstream privilege on which was a large amount of property likely to be damaged in case of failure of the dam.

The writer was employed by the grantor, and another member of the State Board represented the state. Quite a serious controversy arose, in which several engineers took part. The final result was a much safer dam than the owner would have built had he depended on his own engineer.

The following interesting question arose on the dam finally built. Is a dam having a substantial amount of earth embank-

ment and depending on non-automatic gates to pass freshet water " built in a substantial and safe manner . . . and . . . strong and secure " in the meaning of the statute?

The State Engineer approved the plans, but the writer declined to do so under the deed, but after certain changes recommended by him had been made in the plans, his employers entered into an agreement allowing the building of the dam in the manner above described.

Such dams are much used in Michigan where the water level in ponds on large watersheds is wholly controlled by Taintor gates, there being practically no spillways except a narrow space through which to float logs.

The twenty-five or more cases in the writer's experience may be divided into three classes.

First: When plans, specifications, and inspection are under the supervision of competent engineers in the employ of the owner. In this class state control is merely nominal.

Second: When the engineer employed by the owner is inexperienced in dam building. Generally such engineers cheerfully modify their plans at the request of the State Engineer, but not always.

Third: When the owner depends on the contractor for his engineering.

In both the second and third cases, the work of the State Engineer has been very important.

In the opinion of the writer the law has done much good in Connecticut, but it is deficient in many respects, among which are the following:

1. There is no provision for a hearing of interested parties.

2. There is no provision for filing plans and specifications, so that any one can tell how a dam is to be or has been built.

3. The State Engineer cannot take the initiative in the case of unsafe dams already built.

DISCUSSION.

PROF. PHILANDER BETTS.* I may say that the state of New Jersey because of the interest aroused by the failure of the dam at Austin, Pa., enacted a law last winter, which is now on the

*Chief Engineer of the New Jersey Public Utilities Commission.

statute books, providing that the State Water Supply Commission shall have supervision over all dams, those already built and those to be built, and hereafter no dam can be erected in the state of New Jersey for any purpose without having first the approval of the State Water Supply Commission.

Since the dam gave way at Austin there has been a certain amount of feeling of uncertainty in some places, in the northern part of the state, where most of the dams are located that could be considered sources of danger to the communities, and on the part of the Public Utilities Commission we have already sent an engineer to inspect three of these dams. They were earth dams, and only one of them was located in a position where it was really a potential danger to any number of persons. An examination of it showed that no dam ought to be constructed in the way that this particular one was, but under the existing conditions it did not appear to be sufficiently dangerous to take any action in the matter.

The Public Utilities Commission in New Jersey is charged with requiring every public utility to keep its property in such condition as to enable it to render safe, proper, and adequate service. There is some difference of opinion as to whether that power and that responsibility extend to the keeping of a property in such condition as to prevent its becoming a danger to outsiders. The jurisdiction of the Public Utilities Commission is usually supposed to be exercised, at least in accordance with the New Jersey law, in such a way as to provide that the users of the service of a particular company will receive safe, proper, and adequate service, without reference to whether the existence of the plant of the particular company may be a serious danger to others than the users of the utility. The law requires that the company must keep its property so as to furnish good service, but the public utilities law does not extend to putting on the Utilities Commission the responsibility of seeing that the particular plant is not in itself a source of danger because of its existence, that is, either to the customers themselves or to others.

Nothing has yet been done by the Water Supply Commission in connection with the administration of the law. New Jersey, with the exception of the northern portion, is a fairly flat state,

and the flatter portion of it, the eastern and southern sections, have a number of small ponds. In two cases the available head is about forty feet. One of them, located at Millville, is so located with reference to the town that the breaking away of the dam would result in serious damage to a very considerable portion of the town. Most of the ponds, however, are small, furnishing power for grist mills, etc., ranging from five to, say, nine feet head. With the two exceptions noted above, they are small in area, and below them lie no communities that would suffer in case the dam gave way altogether.

About three weeks ago I was looking over a dam about twenty miles southeast from Camden, which is not now connected with the operation of the company in question. This dam had been in existence as an earth dam for a great many years. The old mill had been owned by father and son. They had installed a small steam-driven electric plant which included a 50-h.p. turbine, but after they came to operate it they found there was not water enough to take care of it, so that as a source of electrical energy it did not amount to very much. Some examination, however, was made of the drainage area, and property was obtained and a scheme for a new dam laid out. The whole matter was left in the hands of the young man by the father. Neither father nor son was an engineer, and the dam was built entirely by guesswork, and bore some resemblance to the foundation wall of a building. It lasted for a day and a half. The experience there, while no damage was done to others than the owners of the property, really showed the necessity for some sort of supervision over that sort of thing. Of course you may say that a person has a right to spend his money and waste it in whatever way he likes; but as a rule these things are potential dangers and ought to be, I think, under some kind of supervision.

In the northwestern portion of the state, the hilly portion, the population is more scanty, and the dams that are found there are used only for the operation of grist mills, with the exception of two. One supplies the power for a small electric plant of perhaps 75 h.p., located at Branchville, Sussex County, and the other is located at the mouth of Paulins Kill where it empties into the Delaware River opposite Portland, Pa. At that location they

have available a capacity for about 800 kw. The dam which is at present in place, was put in to replace a dam which was carried out a few years ago. The number of dams that have been carried away in these comparatively unimportant situations rather goes to show that enough study has not been given to the proper construction of dams before they were actually constructed.

Mr. Alexander Rice McKim.* I did not come here to make an address. I only heard of this meeting yesterday afternoon, and I thought that if a busy lot of men, as engineers usually are, could leave New England at the busiest season of the year to come to Washington, they would be a body well worth seeing. I thought they must be mostly millionaires if they were able to get away at this time. That is one reason why I came, because I wanted to see you; and besides, I thought I might be able to pick up a little information.

The Conservation Commission of New York has a Department of Inspection of Docks and Dams, but it is practically a department simply for the inspection of dams, for the law gives us jurisdiction only over structures which impound water, and so far I have not been able to find any docks which impounded water. Previous to the passage of the conservation law, there was absolutely no inspection, or no record kept of dams in the state of New York, but since July, 1911, all dams which are to be constructed or reconstructed or renewed in any way have had to have the approval of the commission. The law also provides that if there is any dam which the Commission considers dangerous, or in any way a menace to life or property, they can cause it to be repaired or removed. There is, moreover, a penalty of five hundred dollars a day for owners who do not carry out the instructions of the commission. We have therefore the hearty coöperation of all the owners, which is a very important factor. Without this penalty clause, the law would be a farce and the department useless.

I happen to have here the requirements for plans to be submitted to the Conservation Commission, and as this is right in line with this discussion, I think it would be in place to give it here:

* Inspector of Docks and Dams, New York State Conservation Commission.

"Before the erection, reconstruction, alteration, or extension of a structure for impounding water, or a structure within the natural and ordinary high-water mark of any stream, the owner, lessee, or the authorized agent, engineer, or builder employed by such owner or lessee for the proposed structure, shall submit, in duplicate, to the Conservation Commission complete specifications and prints, in plan, elevation, and section, showing the location of the dam, the flow line of the impounded water, and the ownership of the property affected, the exact nature of the foundation bed, the character of the materials to be employed, the size and the location of the discharges, the general and special features of the dam, and such dimensions as are necessary for the calculation of the stresses and the erection of the structure. The size of drawings should be 24 in. wide by 36 in. long, with a space inked in to print white on the lower right-hand corner of the tracings 3 in. by 6 in. long for the stamp of approval. When the design is approved by the commission, one set of specifications and prints will be returned, duly stamped and signed. After the site has been cleared and prepared, before permission can be granted to commence erection, the name and a statement of the experience of the inspector for the work must be sent to the commission, a sample of at least one half a cubic foot of sand and twenty cubic inches of each of the other materials to be employed in the structure must be sent to the commission, and the site must be inspected by the commission."

You will see that after the plans have been approved there are yet three conditions to be fulfilled.

First, a statement of the experience of the inspector on the work is required. I have found several defective dams in which the defects should have been detected if competent inspectors had been employed who knew anything at all concerning materials and the work, and, upon inquiry, found that such was not the case. So I put this clause in in order to bring to the mind of the owner or officials that it is necessary for the man who inspects the work to know something about it, and, if he has to sit down and write such a statement, it just sets him thinking.

Second, the materials must be inspected. These materials are sent to the State Laboratory for inspection, which is one of the best equipped and managed laboratories in the country. Generally, the cement and stone give us little trouble, but we have great difficulty in some parts of the state in getting good sand. The

failure of the dam at Port Henry was due entirely to the use of a sand the particles of which were coated with a fine, insoluble loam, which prevented the setting of the cement.

Third, The site must be inspected. This is to be sure that the dam has a good foundation and that it is properly prepared according to the plans and to our requirements.

With regard to the organization, our commission is fortunate. We have under us about two hundred game wardens and forest fire patrolmen, who cover the whole state of New York. These are furnished with blank forms on which each is to report on the dams in his district. They fill these forms out to the best of their ability and send them in; some of these reports are excellent, and others are not as good, but they at least locate the dams of the state, for no one knows at present where they are or anything about them. The men are also instructed, if they find a leak, or a crack, or anything which looks dangerous, or if there is any apprehension concerning the safety of any dam, to report it at once.

Besides these men I have a number of assistants who are going systematically through the different counties doing the above work. We also receive many letters and petitions requesting examinations, and some of these are from owners. These three sources supply us with information concerning the dams of the state. Wherever there is a complaint, or a probable weakness, I give the dam a personal examination. If dangerous, I request the water lowered to what I consider safe limits until the dam has been reinforced to the satisfaction of the commission; and generally this is sufficient.

Last January our commission adopted a code for dams, but it has not been printed yet, because we are trying it out first. As we ascertain the reasons for weakness in or failure of dams, we change the code to correct these features or conditions. A number of the requirements are entirely new, and I think they may be of interest to this body. If you will permit me, I will read just a few of the new clauses, leaving out the standard clauses with which you are all familiar:

"Rock excavation must be done with very light charges of explosives, but, wherever blasting is liable to injure the bed upon

or against which the masonry is built, excavating must be done by wedging and barring or other approved methods."

I find that a favorite method of making the necessary channels and trenches in the rock is to put in dynamite and blow everything to pieces. I have seen them blast good rock all to pieces, where there was a natural channel a few feet off, simply because on the drawing it showed a channel underneath one part of the dam. Explosives of all kinds, I think, are dangerous in the hands of men who do not understand their power, as they are liable to open up fissures. That is one of the reasons why so much water is lost underneath the dams and we have an under-upward water pressure.

Then as to the calculations for the water pressure, we require that —

"All dams must be stable at any section and under all conditions. Dams must be figured to resist the pressure of the highest possible flow, both perpendicularly against the upstream face and the probable upward pressure under the dam; and also to resist the probable pressure of ice.

"For thin walls the compression on masonry must not exceed 10 tons per square foot. For solid masonry dams of over 150 ft. in height with the best of work and materials, and erected under the supervision and inspection of experienced engineers, the compression on upstream face may be 18 tons per square foot and on the downstream face 14 tons per square foot."

This is allowing a pretty good pressure on large masses of concrete which will be well built, as, for instance, the work of the Board of Water Supply of New York City.

"No allowance shall be made in the calculations for steel in solid masonry dams."

I do not believe in building a thin dam and then putting rods in to take up the necessary tension to hold it down. Because, in order to stretch the rods sufficiently to take up the stresses calculated, the dam must move, and when once it commences to move, — nothing can stop it. A gravity system must stand in place by gravity and gravity alone. If engineers wish to put

in steel to bind the whole together, or as an extra precaution in anchorage, well and good.

"In reinforced concrete beams, the allowable compression in the concrete should be 500 lb. per square inch, the ratio of the moduli of elasticity of steel to concrete shall be taken as fifteen, and the ratio of the area of steel reinforcement to the effective area shall be one and one-half per cent."

I find that in reinforced concrete dams even the best of companies are putting 14 000 lb. per square inch on their steel, and others 16 000. The above clause reduces the allowable tension to 8 000 lb. I believe, with further investigation, that it is probable that we will decrease instead of increase the above allowable stresses on steel and concrete.

"The reinforcement at any section parallel to the shear must be sufficient to take up the shear by means of diagonal bars, as well as to provide for tension due to the bending moment by means of bars in the lower or upper flanges, wherever such tension occurs."

The shear is given little and often no consideration in the calculations. If the lower side of a dam is sufficiently reinforced to take the tension, designers often think that is all that is necessary. But a reinforced concrete beam, even with a few thousand pounds stress on the steel, will crack to the center. So the concrete cannot take up the shear and the iron has got to provide for it and should in part therefore be placed diagonally.

For sand we allow as much as seven per cent. by weight of clay and loam, "if fine and divided and all but two per cent. easily dissolved in water."

Now, as to spillways:

"All dams must be provided with durable spillways of sufficient size to prevent the highest possible flow escaping over any part of the dam where no provisions have been made for such escape, or the highest flow coming within the distance of the top as prescribed under earth dams; and without depending for relief upon the operation of any mechanism not automatic and approved of by the highest authorities."

I do not believe in sluiceways to relieve a flood. The man you are depending upon is never there; he is sick, or something else when the flood comes. And, when sluiceboards get a foot or two of water over them, they cannot be raised, even if the watchman is present and active.

Another thing. What is the sense in having a spillway to take care of the flood and then filling it full of flashboards fastened down? So we specify:

"Flashboards may be used in spillways up to a height of one half the clear height of the spillway, if the flashboards are not fastened in any way and if they will float off by their own buoyancy when overtopped by the water. The uprights, against which the flashboards rest, may be fastened to the spillway, but the top of the upright should be inclined slightly downstream."

I think I will not take up any more of your time now. The other provisions in this code you will get in due course, when the code is printed. I think it will be up to the times and will contain a great many things which have never been put in specifications before; and when it is printed I hope to have the coöperation of engineers all over the country, and if there are any defects we should like to have them pointed out. This is not the work of one man; we want the consensus of the opinions of engineers so as to get the very best standard for the state of New York. I thank you very much for your attention.

Mr. T. H. McKenzie. Is this a part of the standard specifications you send to engineers?

Mr. McKim. This is from the code that we are getting out for their use.

Mr. McKenzie. And you send it to engineers who are planning dams before they plan them?

Mr. McKim. That is the idea.

Mr. McKenzie. Speaking of gates, do you allow the use of Taintor gates operated by power?

Mr. McKim. That is a question. I do not like the idea myself of relying entirely on Taintor gates, although we have passed them. If these gates were automatic and reliable, or could be so made, I would have no objection, but when they have to be

operated by mechanism which may be out of order at the critical moment, or the person who is going to operate them may not be there, I do not approve of them.

Mr. McKenzie. I wanted to know what you said in your specifications.

Mr. McKim. That is what we say, — that they cannot rely on any mechanism for relieving the flow which is operated automatically.

Mr. Arthur A. Reimer. I would like to ask Mr. McKim if the code from which he has quoted is in such form that if we were to write to him as individuals we could get at least some of the principal points from it.

Mr. McKim. Certainly; I have many letters every week of that kind. If you will state the character of the dam, whether stone or earth, I will give you everything we have bearing upon it, and will be glad to do so. I am doing it right along.

Mr. Reimer. I am not living in New York, and I was simply wondering if we, as members of the Association interested in engineering subjects, could get it.

Mr. McKim. I would be glad to send the whole code to you as soon as the commission has it printed.

Mr. Reimer. It seems to me that we have had a very good line of specifications or provisions given us by Mr. McKim, and some very happy ideas, and I wish that he might allow the Association to have a copy of the full code so that it could be incorporated in the report of these proceedings, at any rate. Could you furnish it to us?

Mr. McKim. I will ask permission to do that. It has not been given out as a whole yet, and there is a power above me which must be consulted. I am willing personally to give out all I can, whenever I can.

Walter C. Simmons, Esq.* (*by letter*). The following is the Act creating the Commissioner of Dams and Reservoirs of the State of Rhode Island. Although it has been amended in a few unimportant points, it is practically as the act now stands on the statute books.

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* Commissioner of Dams and Reservoirs, Providence, R. I.

General Laws of the State of Rhode Island and Providence Plantations.

Chapter 124.

(AS AMENDED TO APRIL 13, 1906.)

Of the Inspection of Mill Dams and Reservoirs.

Section 1. The governor shall at the January session of the general assembly in the year 1901 and in each third year thereafter, with the advice and consent of the senate, appoint some competent civil engineer to be commissioner of dams and reservoirs. The person so appointed shall hold his office until the first day of February in the third year after his appointment. Any vacancy which may occur in said office when the senate is not in session shall be filled by the governor until the next session thereof, when he shall, with the advice and consent of the senate, appoint some such person to fill such vacancy for the remainder of the term.

Sec. 2. The commissioner of dams and reservoirs shall make a thorough inspection of every dam and reservoir in the state as often as may be necessary to keep himself informed of the condition thereof; and shall make and keep a record of the result of such inspection, with whatever knowledge he shall obtain in reference to each dam or reservoir, and shall make an annual report of his doings in his said office, in the month of January, to the governor.

Sec. 3. Every person owning, maintaining, or having control of any dam or reservoir shall, upon written request therefor, furnish to the commissioner of dams and reservoirs as full, true, and particular description of such dam or reservoir as may be practicable; and shall, as soon as may be after said request, cause to be made all such necessary surveys, plans, and drawings thereof as may be required by the commissioner.

Sec. 4. No dam or reservoir shall be constructed or substantially altered until plans and specifications of the proposed work shall have been filed with, and approved by, the commissioner.

Sec. 5. The commissioner, on application made to him in writing by any person owning or representing property liable to injury or destruction by the breaking of any dam or reservoir, or on such application made by any mayor or board of alderman of any city, or by the town council of any town, on account of danger of loss of life, or of injury to any highway or bridge therein, from the breaking of any dam or reservoir, or, without such complaint, whenever he shall have cause to apprehend that any dam or reservoir is unsafe, shall forthwith view and thoroughly examine such dam or

reservoir. And if in the judgment of the commissioner such dam or reservoir be not sufficiently strong to resist the pressure of water upon it, or if from any other cause the commissioner shall determine such dam or reservoir to be unsafe, or if in his judgment there is reasonable cause to believe that danger to life or property may be apprehended from such unsafe dam or reservoir, the commissioner shall determine whether the water in such reservoir shall be drawn off in whole or in part, and what alterations, additions, and repairs are necessary to be made to such dam or reservoir to make the same safe, and shall forthwith, in writing under his hand, notify the owner or person having control of such dam or reservoir to cause such additions, alterations, and repairs in said dam or reservoir to be made within a time to be limited in such notice; and may order the water in said reservoir to be drawn off, in whole or in part, as said commissioner may determine.

Sec. 6. If the owner or person having the control of any dam or reservoir, who shall be required to draw off the water, or a portion of the water, in any reservoir, or to make alterations in any reservoir, or repairs thereon or additions thereto, in the manner prescribed in the preceding section, shall not forthwith proceed to comply with such requirement, or shall not prosecute the work, when commenced, with reasonable expedition, the commissioner of dams and reservoirs shall make out a complaint in which he shall set forth the condition of the said dam or reservoir, and the steps he has taken to cause the water to be drawn off therefrom and for the alteration or repair thereof, or to have additions made thereto to secure the safety of such dam or reservoir, and the default of the owner or person having control thereof in drawing off the water, repairing, altering, or in making addition to such dam or reservoir, and that the safety of life and property is endangered by such default, and shall subscribe the same, and deliver such complaint to the attorney-general or to the assistant attorney-general, who shall present the same to the appellate division of the supreme court, with a petition in the nature of an information, *ex-officio,* praying that the person owning or controlling such dam or reservoir may be required and ordered forthwith to comply with the requirements of the commissioner of dams and reservoirs theretofore made in the premises, or with such other orders as may be made by the court, to secure all persons having reasonable cause to apprehend injury to life or property from the unsafe condition of such dam or reservoir. Upon the filing of such petition a citation shall issue to the person controlling or owning such dam, commanding him to appear at a time and place therein named, to show cause, if any exists, why the relief prayed for shall not be granted; and the court shall summarily proceed to hear the

said cause; and upon hearing the parties, or by proceeding *ex-parte*, if the respondent fail to appear, the court may pass such order and decreee in the premises as will effectually secure the persons interested from danger or loss from the breaking of the dam or reservoir complained of; and the court may enforce such orders and decree by injunction, process for contempt, by sequestration, or by such other process as may be applicable in such cases.

Sec. 7. The commissioner to be appointed under the first section of this chapter may employ a consulting engineer in any specific case in which the exigencies of the case may require it. The compensation of such consulting engineer shall be allowed by the governor, and be paid, upon the order of the state auditor, out of any money in the treasury not otherwise appropriated.

Sec. 8. All necessary expenses incurred by the commissioner of dams and reservoirs in the discharge of his duty shall be paid from the funds of the state, upon presentation of the proper vouchers approved by the governor: *Provided*, that not more than three hundred and fifty dollars shall be expended by said commissioner in the aggregate in any one year. For the purpose of carrying this act into effect the sum of three hundred and fifty dollars, or so much thereof as may be necessary, is hereby appropriated out of any money in the treasury not otherwise appropriated; and the state auditor is hereby authorized to draw his orders on the general treasurer from time to time for such sums as may be necessary, upon the presentation of properly authenticated vouchers.

Sec. 9. Said commissioner may, in the discharge of his duties, enter upon and pass over private property without rendering himself liable in an action of trespass.

CERTAIN LEGAL ASPECTS OF WATER-POWER DEVELOPMENT IN MAINE.*

BY CYRUS C. BABB, M. AM. SOC. C. E.,

CHIEF ENGINEER, MAINE STATE WATER STORAGE COMMISSION.

[*Read September 18, 1912.*]

INTRODUCTION.

The writer approaches this subject with considerable hesitancy, as he makes no pretensions to a training in law. He was impelled to look into the law of waters by the numerous requests that were received in the office of the Commission regarding the legal features of water-power development in the state of Maine. Furthermore, certain questions occurred to him in his consideration of a policy to be adopted by the state for the development of its water-powers, or, as the Water Storage law requires, "to report a comprehensive and practical plan for the improvement and creation of such water-storage basins and reservoirs as will tend to develop and conserve the water-powers of the state."

Extracts from a number of decisions have been noted that have been of great interest to the writer as bearing directly on the subject-matter, and it is believed will be of general interest to engineers, especially to those practicing in New England. The quotations given below are more in the nature of an introduction to a proposed bill providing for state supervision of the construction of dams, the regulation of storage reservoirs, and the taxation of water-powers.

A large number of court decisions have been read, but the citations given below are intended to represent general principles and not special or unusual cases. Full references are given, so that the facts on which the decisions were based can be looked up, and the subject pursued further if desired, as each case generally has references to other similar ones.

FEATURES OF LAW.

Water-power and water-storage developments in Maine have been based mainly, in so far as legal features are concerned, on the

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* A table of contents for this paper will be found on page 226.

Colonial Ordinances of 1641–47; the so-called Mill Act; the common law of waters; to a lesser degree, the act relating to the improvement of marshes, meadows, and swamps; the several acts relating to the procedure for the organization of corporations; and the various decisions of the law courts of the state of Maine bearing on these acts.

Colonial Ordinances, 1641–47.

This act, first adopted by the General Court of the Colony in 1641 and amended in 1647, reads as follows:

Liberties Common.

2. Every inhabitant who is an householder shall have free fishing and fowling in any great ponds, bayes, Coves, and Rivers so far as the Sea ebbs and flows, within the precincts of the towne where they dwell, unless the freemen of the same Towne or the General Court have otherwise appropriated them. Provided that no Towne shall appropriate to any particular person or persons, any great Pond containing more than ten acres of land, and that no man shall come on another man's propriety without their leave otherwise than as hereafter expressed. The which clearly to determine, It is Declared, That in all Creeks, Coves and other places, about and upon Salt-water, where the Sea ebbs and flows, the proprietor of the land adjoining, shall have propriety of the low-watermark where the Sea does not ebb above a hundred rods, and not more wheresoever it ebbs further. Provided that such proprietor shall not by this liberty, have power to stop or hinder the passage of boates or other vessels, in or through any Sea, Creek, or Coves, to other men's houses or lands. And for great Ponds lying in common, though within the bounds of some Towne, it shall be free for any man to fish and fowle there and may pass and repass on foot through any man's propriety for that end, so they trespass not on any man's Corn or Meadow.

A case recently decided by the Supreme Judicial Court of Maine covers in an interesting and thorough, although concise manner, the early history of the various acts of the colonial courts and legislatures upon which the law of Maine is based. (See Conant *v.* Jordan, 107 Me. 227.)

Decisions of Law.

Many decisions have been rendered by the courts on these Colonial Ordinances, among which may be noted the following:

"Although fishing and fowling are the only rights named in the ordinance, it has always been considered that its object was to set apart and devote the great ponds to public use, and that . . . these public reservations, at first set apart with reference to certain special uses only, become capable of many others which are within the designs and intent of the original appropriation. The devotion to public use is sufficiently broad to include them all, as they rise." (West Roxbury *v.* Stoddard, 7 Allen, 158. Watuppa Reservoir Co. *v.* Fall River, 147 Mass. 548, 557.)

It is a rule of law peculiar to Maine and Massachusetts under the Colonial Ordinance of 1641–47 that all great ponds — that is, ponds containing more than ten acres — are owned by the State.

While private property cannot be taken for public use without compensation, the waters of great ponds and lakes are not private property.

Under the ordinance, the state owns the ponds as public property held in trust for public uses. It has not only the *jus privatum*, the ownership of the soil, but also the *jus publicum* and the right to control and regulate the public uses to which the ponds shall be applied.

The authority of the state to control waters of great ponds and determine the uses to which they may be applied is a govermental power, and the governmental powers of the state are never lost by mere non-use. (Auburn *v.* Union Water Power Co., 90 Me. 577.)

The ordinance has been held to be broad enough to justify the state in granting authority to a certain commission to forbid the public navigating the waters of a great pond set aside as a reservoir for water supply. Defendant denied the right of the commissioners to keep him off.

Held: "There is no doubt that the control of the great ponds in the public interest is in the legislature that represents the public. It may regulate and change these public rights or take them away altogether to serve some paramount public interest. . . . The legislature having seen fit to devote the waters of the lake to a public use for the benefit of the inhabitants of the metropolitan water district, it was in its power to deprive the general public of the right to go upon it with boats or otherwise, on the ground

that a safe and advantageous use of the water for drinking, and for other domestic purposes, would be best promoted by terminating this former right and putting the property in the control of the water board." (Sprague *v.* Minon, 195 Mass. 581, 583.)

The waters of great ponds being, by virtue of the ordinance, public waters, may be devoted to any legitimate public use. In the case of Watuppa Reservoir Co. *v.* Fall River, 147 Mass. 548, the city of Fall River was authorized by the legislature to draw daily one million five hundred thousand gallons of water from the North Watuppa Pond (a great pond) and to "apply the water taken under this act to all domestic uses, the extinguishment of fires, and to the public use of the city." The plaintiffs were the owners of manufacturing establishments on the only outlet of the pond and were owners also of the bed and land on either side of the stream, they were incorporated for the purpose of constructing a reservoir in the pond, and had at great expense acquired flowage rights all around the pond, built a dam, raised the water of the pond, and were maintaining their reservoir. The draw-off by the city caused actual injury to plaintiffs, who contended that the statute authorizing such withdrawal of water without compensation to plaintiffs was unconstitutional.

Held: "These are all public purposes. The legislature acting on the conviction that an abundant supply of pure water to the people is of paramount importance, has deemed it to be a wise policy to appropriate the waters of this pond to those public uses without making compensation to those who, owning land on the natural stream flowing from it, have been accustomed to use the water for power as it flows through the stream. Such owners have no vested rights in the waters of the pond, and a majority of the court is of the opinion that the Commonwealth may thus appropriate the waters by its direct action, or may authorize a city or town to do so, without being legally liable to pay any damages to the littoral owners on the pond or on the stream." (Watuppa Reservoir Co. *v.* Fall River, 147 Mass. 548.)

"They [the colonists] reserved to the Colony the property in the ponds themselves, the better to regulate these and other kindred public rights for common good." "The ordinance secures to the Commonwealth, in great ponds, the same kind of

ownership in the water that an individual purchaser of the entire area of a small pond would get by a perfect deed, or by an original grant from the government without restrictions." (Minority opinion, Watuppa Reservoir Co. *v.* Fall River, 147 Mass. 548.)

In the case of the state of Maine, it is to be noticed that the exceptions in the Colonial Ordinance, namely, of ponds "otherwise appropriated" by the freemen of a town, or by the General Court, have never applied here and are not required. We know of no grants by towns, nor by any general court. Here there were no apparent limitations. Here, we feel bound to say, the doctrine of the English common law of private ownership in great ponds was never recognized nor adopted, and fowling on and fishing in them was free from the beginning. (Conant *v.* Jordan, 107 Me. 240.)

The state can at its discretion authorize the diversion of the waters of great ponds for public purposes without providing compensation to riparian owners upon the ponds or their outlets. (American Woolen Co. *v.* Kennebec Water District, 102 Me. 153.)

It is too late in the history of the question in this state to contend that the state has not the constitutional power to grant superior, or even exclusive privileges, in the use of its public rivers to persons or corporations. The state represents all rights and privileges in our fresh-water rivers and streams, and may dispose of same as it seems fit. (Mullen *v.* Penobscot Log Driving Co., 90 Me. 555.)

The extra stores of water collected by the mill owner for his use are his own. They could be taken by the state for the public for a compensation. (Pearson *v.* Rolfe, 76 Me. 389.)

The water of the great natural ponds or lakes cannot be lawfully drawn down below their natural low water line, without legislative authority; nor under the mill act.

A bill in equity may be maintained by the owner of land bounded on a great pond to restrain by injunction mill-owners on the outlet

from drawing off the water in such pond below its natural low-water mark by excavating the channel or deepening the outlet. (Fernald *v.* Knox Woolen Co., 82 Me. 48.)

Lands bounded upon rivers above the ebb and flow of the tide generally extend to the middle of the stream, but lands bounded on fresh-water lakes and ponds extend only to low-water mark. (Stevens *v.* King, 76 Me. 198.)

It seems that land bounded on a natural lake or pond extends only to the water's edge; otherwise if the pond is artificial. (Robinson *v.* White, 42 Me. 209.)

In the conveyance of land bounded on a fresh water pond, which has been permanently enlarged by means of a dam at its mouth, the title extends to the low-water mark of the pond, in its enlarged state. (Wood *v.* Kelley, 30 Me. 47.)

The rule of common law, that riparian proprietors own to the thread of fresh water rivers, has been adopted in this state. (Brown *v.* Chadbourne, 31 Me. 9.)

Below the line of low water, the state owns the beds of navigable rivers and great ponds, and holds them in trust for the public in accordance with the Colonial Ordinance of 1647. (Haynes *v.* Dewitt Ice Co., 86 Me. 319.)

A navigable stream is subject to public use as a highway for the purpose of commerce and travel.

All streams of sufficient capacity in their natural condition to float boats, rafts, or logs, are deemed public highways and as such are subject to the use of the public.

Held: "That the Presque Isle stream above the bridge at Presque Isle village, for a distance of thirty miles, is a navigable stream in fact, etc., applies to passage of stream by boat or canoe." (Smart *v.* Aroostook Lumber Co., 103 Me. 37.)

The Mill Act.

This act (Rev. Stat., Chap. 94) had its origin in Massachusetts in the early part of the last century and has been continued

with slight modifications both in that state and in Maine to the present time. The principles have been handed down in these two states alone, although some features of them have been adopted by neighboring states. The object of the statute, in the preamble to this law at its origin, was as follows:

"Whereas, it has been found, by experience, that when some persons in this province have been at great cost and expenses for building of mills serviceable for the public good and benefit of the town, or considerable neighborhood in or near to which they have been erected, that in raising a suitable head of water for that service, it hath sometimes so happened that some small quantity of lands or meadows have been thereby flowed and damnified, not belonging to the owner or owners of such mill or mills, whereby several controversies and law suits have arisen, for the prevention whereof for the future. Be it therefore enacted," etc. (Ancient Charters, p. 404.)

In 1795, February 27, the legislature of Massachusetts passed an additional or amendatory act, the preamble and first section of which are as follows:

"Whereas, the erection and support of mills to accommodate the inhabitants of the several parts of the state ought not to be discouraged by many doubts and disputes; and some special provisions are found necessary relative to the flowing of adjacent lands, and mills held by several proprietors. Therefore, be it enacted," etc.

"That when any person hath already erected, or shall erect any water mill on his own land or on the land of any other person, by his consent legally obtained, and to the working of such mills it shall be found necessary to raise a suitable head of water; and in so doing any lands shall be flowed not belonging to the owner of such mill, it shall be lawful for the owner or occupant of such mill to continue the same head of water on the terms hereinafter mentioned."

This provision was incorporated into our statutes in 1821.

The intent and main features of the Mill Act in question are contained in the first four sections, which are as follows:

ERECTION OF MILLS AND DAMS, AND RIGHTS OF FLOWAGE.

Sec. 1. Any man may on his own land, erect and maintain a water mill and dams to raise water for working it, upon and across any stream, not navigable; or, for the purpose of propelling mills

or machinery, may cut a canal and erect walls and embankments upon his own land, not exceeding one mile in length, and thereby divert from its natural channel the water of any stream not navigable, upon the terms and conditions, and subject to the regulations hereinafter expressed.

Sec. 2. No such dam shall be erected or canal constructed on the same stream; nor to the injury of any mill site, on which a mill or mill dam has been lawfully erected and used, unless the right to maintain a mill thereon has been lost or defeated.

Sec. 3. The height to which the water may be raised, and the length of time during which it may be kept up in each year, and the quantity of water that may be diverted by such canal, may be restricted and regulated by the verdict of a jury, or report of commissioners, as is hereinafter provided.

Sec. 4. Any person, whose lands are damaged by being flowed by a mill-dam, or by the diversion of the water by such canal, may obtain compensation for the injury by complaint to the Supreme Judicial Court in the county where any part of the lands are; but no compensation shall be awarded for damages sustained more than three years before the institution of the complaint.

Decisions of Law.

Numerous decisions of the courts of Maine on the Mill Act have been rendered from time to time, among which are the following:

Private property shall not be taken for public uses without just compensation; nor unless the public exigencies require. (Const., Art. 1, par. 21.)

The Mill Act, as it has existed in this state, pushes the power of eminent domain to the very verge of constitutional inhibition. If it were a new question, it might well be doubted whether it would not be deemed to be in conflict with that provision of the Constitution cited above. (Jordan *v.* Woodward, 40 Me. 323.)

Even the reasons for the policy which occasioned such legislation have ceased to be potential, and although from the long and uninterrupted exercise of the rights of mill-owners, under this act, it must be considered constitutional, yet, no extension of their rights over private property can be allowed by implication. (Jordan *v.* Woodward, 40 Me. 317.)

The constitution of the state, Art. 1, Sect. 21, in the Declaration of Rights, provides that "private property shall not be taken for public uses, without just compensation, nor unless the public exigencies require." And it is held to be necessarily implied that private property cannot be taken for private uses without the consent of the owner, with or without compensation.

Private property may be taken by the sovereign power of the government in the exercise of the right of eminent domain for purposes of public utility.

Interests in water, as well as in land, may be taken by virtue of this power, and both are equally the subjects of compensation. (Hamor *v.* Bar Harbor Water Co., 78 Me. 127.)

Whether a public exigency exists for the granting of the exercise of the right of eminent domain, is for the legislature to determine. Whether the use for which it is granted is a public one, the court must decide. (Brown *v.* Gerald, 100 Me. 352.)

Whether there is such an exigency, — whether it is wise and expedient or necessary that the right of eminent domain should be exercised, in case the use is public, — is solely for the determination of the legislature. The legislature however cannot make a private use public by calling it so. Whether the use for which it is granted is a public one must in the end be determined by the court. (Brown *v.* Gerald, 100 Me. 360.)

These cases relate to railroads, water companies, boom companies, canals, and the improvement of public streams. As to such cases there is now no doubt. Their uses are rightly deemed public. The public, or such part of the public as has occasion to, may directly enjoy them. Such uses are of great public benefit. (Brown *v.* Gerald, 100 Me. 361.)

We think it should be conceded that the taking of land for the purpose of supplying the public, or so much of the public as wishes it, with electric lighting, is for a public use. . . . The charter unquestionably gives the company the right of eminent domain for the purpose of supplying a current for electric lighting. (Brown *v.* Gerald, 100 Me. 356.)

Saw mills and grist mills, carding mills and fulling mills, cotton gins and other mills, which are regulated by law, and obliged to serve the public, are undoubtedly a public use. But, as respects all other kinds of mills, although they may be a public benefit, they are not a public use within the meaning of the constitution. (State *v.* Edwards, 86 Me. 102.)

Manufacturing, generating, selling, distributing, and supplying electricity for power, for manufacturing or mechanical purposes, is *not* a public use for which private property may be taken against the will of the owner.

A corporation empowered by its charter to generate and transmit electric power, for lease or sale, and having granted to it the right of eminent domain, does not by accepting the provisions of its charter become a quasi-public corporation, and does not thereby become invested with the right to exercise the eminent domain for the purpose of supplying electric power for manufacturing purposes. (Brown *v.* Gerald, 100 Me. 352.)

The legislature has the constitutional power to authorize the erection of dams upon non-tidal public streams to facilitate the driving of logs, without providing compensation for mere consequential injuries where no private property is appropriated.

Where such a dam, erected in accordance with legislative authority, causes an increased flow of water at times in the channel below, thereby widening and deepening the channel and wearing away more or less the soil of a lower riparian owner, it is not such a taking of private property as entitles the owner to compensation. It is a case of *damnum absque injuria.* (Brooks *v.* Cedar Brook & C. Imp. Co., 82 Me. 17.)

By our Mill Act., Rev. Stats., Chap. 94, any person may build upon his own land across a non-navigable stream a water-mill and dams to raise a head of water for working it, and may thereby flow back the water of the stream upon the lands above as high and as far as he deems necessary for the profitable working of his mill, subject only to the conditions and restrictions named in the act itself. The land owners must submit to the flowage, and content themselves with the pecuniary compensation to be obtained through proceedings provided by the statute. Such mill owner

can also in the same way increase the height of his dam and the extent of the flowage from time to time as the exigencies of his business may seem to him to require, he making increased compensation for the increased flowage.

But there is one important and absolute exception to the above-named statutory right to retard the natural flow of a stream: "No such dam shall be erected (or canal constructed) to the injury of any mill (or canal) lawfully existing on the same stream." (Section 2 of Mill Act, Rev. Stats., Chap. 94.) It follows, as a corollary, that when a second mill has been built above the flowage of the first and older mill and dam, such flowage cannot be increased by raising the dam or by other appliances so as to lessen the original efficiency of the mill above. Whatever the greater age of his mill, the right of a mill owner to increase his head of water ceases when the flowage begins to injure the operation of a mill, however new, if already lawfully erected before the injurious flowage began. So long, however, as the additional flowage does not reach up so far as to injuriously affect some mill by that time lawfully erected, the right to increase the flowage is unlimited except as limited by the statute itself. This increase can be effected by raising the height of the solid dam, by the use of flashboards, or by other appliances. The owners of *unoccupied* water powers, or mill sites, must submit to have them flowed out and made useless, and must content themselves with the statutory compensation. (National Fibre Board Co. *v.* L. & A. Electric Co., 95 Me. 321.)

The plaintiff whose land has been overflowed by a *reservoir dam* erected by the defendants upon their own land, but for the use of a mill not owned by them nor standing upon their land, may maintain an action on the case for the damages caused by such dam. The process by complaint, under Rev. Stats. 94 (Mill Act), cannot be sustained upon these facts. (Crockett *v.* Millett, 65 Me. 191.)

As between proprietors of dams on the same stream, he has the better right who was first in point of time.

Unless the plaintiff abandoned his site, the temporary destruction of his dam would not enable the defendant to acquire, as against the plaintiff, the right of a prior occupant. (Lincoln *v.* Chadbourne, 56 Me. 197.)

Mill owners have a right to maintain their dam as it was at the time of the deeds to them; and if, through want of repair for a series of years subsequent to that, it lets the water escape, the owners have the right to repair and tighten it, although the water is thereby raised higher and retained longer than it was while the dam was in a dilapidated condition. (Butler *v.* Huse, 63 Me. 447.)

Natural Flow.

Thurber *v.* Martin, 2 Gray, 394, was an action of tort for obstructing the natural flow of the water, and diverting it from the plaintiff's mill. In delivering the opinion of the Court, Chief Justice Shaw thus stated the law of the case:

"Every man has the right to the reasonable use and enjoyment of a current of running water, as it flows through or along his own land for mill purposes, having a due regard to the like reasonable use of the stream by all the proprietors above and below him. In determining what is such reasonable use, a just regard must be had to the force and magnitude of the current, its height and velocity, the state of improvement in the country in regard to mills and machinery, and the use of water as a propelling power, the general usage of the country in similar cases, and all other circumstances bearing upon the question of fitness and propriety in the use of the water in the particular case." (Davis *v.* Winslow, 51 Me. 292.)

Every proprietor of land on the banks of a river or stream has naturally an equal right to the use of the water; and this right to use implies a right to control, detain, and even diminish the volume of the water, — but only to a reasonable extent.

What is a reasonable detention depends upon the size of the stream, as well as upon the uses to which it is subservient, as the detention must necessarily be sufficient to accumulate the head of water requisite for practical use.

The right of detention is not limited to time necessary for repairs or to extraordinary occasions, but applies to the ordinary use of such streams, provided it be not an unreasonable use or detention. (Davis *v.* Getchell, 50 Me. 602.)

Thus he may apply it to domestic purposes or purposes of irrigation, but not to such an extent as unreasonably to diminish its quantity. (Davis *v.* Getchell, 50 Me. 604.)

In Pitts *v.* The Lancaster Mills, 13 Metcalf, 157, the defendants, owners of a mill and dam above an ancient mill dam of the plaintiffs, rebuilt and raised that dam above its former height, whereby the water was wholly cut off from the plaintiff's mill for a period of six days, greatly to his detriment. The case was submitted to the Court upon an agreed statement of facts, and a non-suit was ordered, the Court assigning as a reason therefor, that "this was not an unreasonable use of the watercourse by the defendants, and that any loss which the plaintiffs temporarily sustained by it was *damnum absque injuria.*" (Davis *v.* Winslow, 51 Me. 292.)

A mill owner has no right to unnecessarily and unreasonably detain water from those who have a right to use it subsequent to his own; and he will be liable in damages for doing so.

What is a reasonable use and what an unreasonable detention, are questions of fact for the jury. (Phillips *v.* Sherman, 64 Me. 171.)

The new dam raised the outlet some three feet, and held the water at that level, but did not divert it. No more water was thereby taken from the stream than the capacity of the 24-in. pipe would divert. That quantity might be taken, even if no water should be left to flow in the natural channel. The natural flow was substantially the same with the new dam as with the old or without any dam. (Hamor *v.* Bar Harbor Water Co., 92 Me. 364, 377.)

In the case of Mullen *v.* Penobscot Log Driving Co., 90 Me. 555, the defendant was a company chartered by the legislature for driving all logs of all owners in the West Branch waters, and the company was given the exclusive control and management of the waters of the river, so far as necessary to enable it to successfully execute the obligations resting upon it, an obligation in some respects partaking of the character of a public trust.

Held: the plaintiff was not entitled even to the natural flow or to draw from the reserves of water in order to create what would at the time and place be equivalent to the natural flow, so long as the company needed or would be likely to need the same water for driving its own logs to market. The defendant's right was the superior right. The plaintiff's right was secondary and conditional. Such is the inevitable effect of the grants to the company by the legislature. The stores of water are accumulated by using the natural flow until the necessary head is obtained. It was not that the defendant company would not let the water down when it needed its use itself, but the plaintiff desired the use and advantages of it in advance of the use of it by the company.

Floatable Streams.

A stream which, in its natural condition, is capable of being commonly and generally useful for floating boats, rafts or logs, for any useful purpose of agriculture or trade, though it be private property, and though it be not strictly navigable, is subject to the public use, as a passageway.

Though the adaptation of the stream to such use may not be continuous at all seasons, and in all its conditions, yet the public right attaches, and may be exercised whenever opportunities occur.

When a stream is inherently, and in its nature, capable of being used for the purpose of commerce, for the floating of vessels, boats, rafts, or logs, the public easement exists.

In such a stream, the right in the public exists, notwithstanding it may be necessary for persons floating logs thereon to use its banks. (Brown *v.* Chadbourne, 31 Me. 9.)

In order to make a stream floatable it is not necessary that it should be so at all seasons of the year. It is sufficient if it have that character at different periods with reasonable certainty and for such a length of time as to make it profitable for that purpose.

The question is whether the stream is floatable without the dam. If it is not, the plaintiff could not avail himself of the fact that it is made so by the defendant's dam. If the stream was originally private property, exclusively so, any improvements made upon it by the owner would give the public no rights on it. But if on the other hand the stream is by nature floatable, those who

have occasion to use it as such may do so and may also have the benefit of such improvements as may be put upon it having reasonable regard to the rights of the owner. (Holden *v.* Robinson Co., 65 Me. 216, 217.)

The judge instructed the jury that if the river in its natural state was capable of being useful for floating boats, logs, etc., for purposes of trade or agriculture, the plaintiff was entitled to recover, however long the dam of the defendant might have stood; and notwithstanding his use of the river had been open, notorious, and adverse, and although no logs had ever been floated over the falls where the dam now is. (Knox *v.* Chaloner, 42 Me. 150.)

Whether a stream is capable of being used as a passageway for the purposes of commerce is a question of fact for the jury. (Treat *v.* Lord, 42 Me. 552.)

The presiding judge instructed the jury that if Cold Stream was such a stream as the public would have an easement in for the driving of logs, on account of its inherent capacity for being so used . . . that the right of way was in the waters, and the plaintiff in such case would have no authority to prevent its exercises; that he could by law erect and continue his dams and mills, but was bound to provide a way of passage for the defendants' logs; that some streams are entirely private property, and some are subject to the public use and enjoyment; that the test has been sometimes held to consist in the fact whether they are susceptible or not of use as a common passageway for the public. And, by request of plaintiffs' counsel, the judge instructed the jury "that if the stream was incapable in its natural state of being used to propel logs without the erection of dams or other structures on plaintiffs' land, there could be no public servitude."

The judge also instructed the jury that the law, as established in this state, and which they would take for their guide, was, that "the true test to be applied in such cases is whether or not a stream is inherently and in its nature capable of being used for the purposes of commerce, for the floating of vessels, boats, rafts, or logs — when a stream possesses such a character, then the easement exists, leaving to the owners all other modes of use not in-

consistent with it"; that a stream might possess such a character, even though, when the forest was first opened on its shores, it were so obstructed by fallen trees, brush and driftwood, that neither vessels, boats, rafts, or logs could be floated, through its course, upon its surface, until such obstructions had been removed; that, perhaps, many such streams, when the forests about them were first opened, would need such clearing out before they could be profitably used; and that it was a question for the jury to determine, from the evidence in the case, whether or not the stream was inherently and in its nature capable of being used for the purposes of commerce, for the floating of vessels, boats, rafts, or logs. (Treat *v.* Lord, 42 Me. 555, 556.)

The controversy in the case of Pearson *v.* Rolfe, 76 Me. 380, arose from a conflict between log-owners and mill-owners as to their respective rights in the use of the water at certain falls in the Penobscot River in the town of Old Town. Pearson represents mill-owners, Rolfe represents log-owners. Pearson has mill structures upon his privilege, with such appendages as dams, sluices, and booms. Rolfe had a quantity of logs in the river which he was unable to drive over the dam at Pearson's mills, *unless Pearson would shut down his mill-gates*, thereby suspending his own business of manufacturing, until water enough should accumulate in his mill-pond to float the logs over. This Pearson refused to do, basing his refusal upon the allegation that the driftway in the dam, without shutting down his working gates, afforded all the facility for floating logs by his mills that existed in the river at that place in its natural state, — as much as there would be, provided his mills and all of his structures were entirely out of the way. Rolfe contends that the facts were otherwise, but further contends that Pearson, even if he represents the facts truly, having it within his power to furnish more water than the natural facility and flow, was under an obligation from his situation to do so.

The counsel for Rolfe contended that the doctrine of *reasonable use* applied; and that, if the river in its natural condition would not furnish a sufficient flow, Rolfe was entitled to the use of the river in its changed condition for his purposes. We think this position cannot be maintained. Our idea is that the doctrine of reasonable

use does not apply when the river is *not* naturally floatable; but does apply when it *is* naturally floatable or log-navigable, when both parties can use the natural flow and desire to use it at the same time. We are well satisfied that, whenever logs cannot be driven over a particular portion of a fresh water river such as the Penobscot, above the flow and ebb of the tide, while in its natural condition, such portion of the river is not at such time navigable or floatable, and that the use of the water at such time, and place, belongs exclusively to the riparian proprietor, so far as he needs the same for his own purposes.

The Penobscot River at the place in question, as before intimated, was floatable only, — floatable, because capable of valuable use in bearing the products of the forests to markets or mills. A floatable stream is the least important of the classes of streams called navigable. Rolfe had the right to use the river so far as it was a floatable river, in such parts or places and at such times as it was floatable. He had the right to avail himself of its navigable capacity for floating logs. But only so far as it was navigable or floatable in its *natural condition.* It is the natural condition of a stream which determines its character for public use, and it must be its navigable properties in a natural condition unaided by artificial means or devices. It is well settled in this state and elsewhere, that, if a stream is not susceptible of valuable use to the public for floatable purposes, without erections for raising a head, it cannot legally be deemed a public stream, even though it might be easily converted into a floatable stream by artificial contrivances. Wadsworth *v.* Smith, 11 Me. 278; Brown *v.* Chadbourne, 31 Me. 9; Treat *v.* Lord, 42 Me. 552; Nuis. (2d. ed.), 463, and cases.

The log driver takes the waters as they run, and the bed over which they flow as nature provides. Nor has any person the right, unless upon his own land, or under legislative grant, to remove natural obstructions from the bed of a river in order to improve its navigation. This is clear from the same authorities.

On the other hand, what rights have the adjudged cases accorded to the riparian proprietor in merely floatable and non-tidal streams? It is settled in this state that he owns the bed of the river to the middle of the stream. He owns all the rocks and natural barriers

in it. He owns all but the public right of passage. The right of passage does not include any right to meddle with the rocks or soil in the bed of the river. If rocks are taken, the owner may sue in trespass for the act, or may replevy them from the wrongdoer. (Pearson *v.* Rolfe, 76 Me. 383–386.)

Let it be borne in mind that the complaint against Pearson is not that he kept back the natural flow, but that he refused to keep it back, — that he would not shut down his gates and suspend his business in order to keep it back. The demand was that he should suspend his own sawing and shut down his mill-gates until the accumulation of water in the mill pond might be enough to create a navigable flow through the public passage. (*Supra*, p. 387.)

Held: A mill-owner upon a floatable river is not under legal obligation to provide a public way, for the passage of logs over his dam, better than would be afforded by the natural condition of the river unobstructed by his mills. The right of passage is to the natural flow of the river or its equivalent.

Held: A mill-owner is not under legal obligation to furnish any public passage for logs over his dam or through his mills at a time when the river at such place, in its natural condition, does not contain water enough to be floatable if unobstructed by mills, although the river is generally of a floatable character.

Held: Whenever a river, with mills upon it, is floatable, and the mill-owner and those who want to float logs past the mills are desirous of using the water at the same time, all parties are entitled to reasonable use of the common boom; the right of passage is the superior, but not an usurping, excessive, or exclusive, right; the law authorizing mills puts some incumbrance upon the right of passage. (*Supra*, p. 380.)

The reasonableness of the use depends upon the nature and size of the stream, the business or purpose to which it is made subservient, and on the ever-varying circumstances of each particular case. Each case must stand upon its own facts, and can be a guide in other cases only as it may illustrate the application of general principles. (*Supra*, p. 390.)

Measurement of Water-Power.

Grants and reservations relating to water and water-power are various in their nature and effect. Some refer to a certain extent of water-power sufficient for the propulsion of a specific mill or

machinery: Warner *v.* Cushman, 82 Me. 168; Hammond *v.* Woodman, 41 Me. 177; Covel *v.* Hart, 56 Me. 518, 522; Elliott *v.* Sheperd, 25 Me. 371; Ashley *v.* Pease, 18 Pickering, 268. Some to a quantity of water to be restricted to a specific purpose: Deshon *v.* Porter, 38 Me. 293. Others to "such quantity of water as the grantor or his predecessor have been accustomed to use": Avon Man'f'g Co. *v.* Andrews, 30 Conn. 476. Still others, to such quantity of water as will flow through a gate of specific dimensions under a specific head of water: Bardwell *v.* Ames, 22 Pickering, 333; Tourtellot *v.* Phelps, 4 Gray, 373. Head is a well-known material factor in determining the quantity of water which will pass through a given aperture in a given time. Canal Co. *v.* Hill, 15 Wallace, 94, 102. (Gray *v.* Saco Water Power Co., 85 Me. 528.)

The United States Supreme Court has held as follows:

A grant of a right to draw from a canal so much water as will pass through an aperture of given size and given position in the side of the canal is substantially a grant of a right to take a certain quantity of water in bulk or weight. What that quantity is may be ascertained from the character and depth of the canal, the circumstances under which the water is to be drawn, and the state of things existing at the time the grant is made.

The grantee will be entitled to draw this quantity even though it may be necessary to have the aperture enlarged if it can be done without injury to the grantor. (Canal Co. *v.* Hill, 15 Wallace, 94.)

Where a grantor, owning all the water-power on both sides of a stream, conveyed the saw mill thereon, "with the right of use of all water not necessary in driving the wheel, or its equal, now used to carry the machinery in the shingle mill, — meaning to convey a right to all the surplus of water not required for the shingle mill or other equal machinery," — and it appeared that, at the time of the conveyance, the shingle mill contained various other machinery besides the shingle machine:

Held, that the parties thereby fixed the measure of the water not conveyed, and that its use was not confined to the specific purpose of driving the shingle machine.

Held, also, that the owner of the shingle mill might lawfully put into it a board saw, and use the same, provided the wheel used for propelling it consumed no more water than was previously used, even if the owner of the saw mill thereby lost all his patrons. (Warner *v*. Cushman, 82 Me. 168.)

A reservation of water necessary and sufficient to carry two run of mill stones.

Held, a reservation of a quantity sufficient for the purpose with the machinery in actual or contemplated use at the mill at the time the reservation was made, and not restricted then or afterwards to such quantity as with improved machinery and facilities would perform the same work.

Held, also, to reserve an absolute right to the use of the quantity of water named; and to be a reservation of a fixed measure of power to be used for any purpose, and not confined to the grist mill. (Blake *v*. Madigan, 65 Me. 522.)

A grant by the owner of a dam of the right to use five hundred square inches of water, for the purpose of creating power, as a substitute for a prior grant, in which the head was not mentioned, carried by implication the right to draw the water from the dam, at the head of which water was ordinarily taken under the prior grant. (Oakland Woolen Co. *v*. Union Gas & Electric Co., 101 Me. 199.)

The Franklin Company, the then owner of a dam lawfully maintained across the Androscoggin River at Lewiston for raising a head of water for generating power, granted by an instrument of indenture to the City of Lewiston the right to draw from its dam " water to the extent of 600 horse-power for the purpose of pumping," etc. (the head of water being fixed at not less than 25 ft. nor more than 30 ft.). After full consideration of the subject matter of the grant, the situation, the history and character of the negotiations, and all the language used by the parties in the instrument finally signed by them as defining their rights and obligations, thereunder, *held:*

a. The grant is not of water-power, but only of water for power, and the city is entitled, not to a certain quantity of power, but only to draw a certain fixed quantity of water from which

to extract as much power as it may by its own agents and appliances.

b. From the evidence and the admissions of the plaintiff it appears that the phrase "to the extent of 600 horse-power" means in its connection, efficient, practical horse-power upon a well-understood and recognized basis of seventy-five per cent. of efficiency, and hence the city is entitled to draw for pumping purposes water to the extent of 800 nominal or theoretical horse-power and no more. (Union Water Power Co. *v.* Lewiston, 101 Me. 565.)

Some time in the 80's an interesting case was tried in one of the Maine lower courts, known as the "Brunswick Water Case." Mr. J. Herbert Shedd testified as to the value of a "saw," a term used in the early days to designate the horse-power required to operate the old undershot and flutter wheels used in the saw mills on the Androscoggin River at Brunswick. His results, based on several different methods of computations, gave one "saw" equal to 120 nominal horse-power, or, "that about 120 horse-power of water might be taken to be the measure of water which was used anciently to run one saw." This was not effective horse-power based on the efficiency of the wheels, but theoretical, based on the discharge and head. He stated that the old flutter wheels had an efficiency of from one sixth to one eighth of the total power, and that the actual power to run an old-fashioned saw was about 15 to 20 horse-power.

IMPROVEMENT OF MARSHES, MEADOWS, AND SWAMPS.

The provisions of Revised Statutes entitled, "Improvement of Marshes, Meadows, and Swamps" (Chap. 26, Sec. 42–70), are important as bearing on developments of water courses in this state although of somewhat lesser importance than the Mill Act previously described. The first five sections read as follows:

Sec. 42. When any meadow, swamp, marsh, beach, or other low land is held by several proprietors, and it becomes necessary or useful to drain or flow the same, or to remove obstructions in rivers or streams leading therefrom, such improvements may be effected under the direction of commissioners in the manner hereinafter provided.

Sec. 43. Such proprietors, or a majority of them in interest, may

apply by petition to the Supreme Judicial Court sitting in the county where the lands or any part of them lie, setting forth the proposed improvements and the reasons therefor, and the court shall cause notice of the petition to be given in such manner as it may judge proper, to any proprietors who have not joined in the petition, that they may appear and answer thereto.

Sec. 44. If upon hearing, it appears that the proposed improvements will be for the general advantage of the proprietors, the court may appoint three suitable persons as commissioners, who shall be sworn to the faithful discharge of their duties; view the premises, notify parties concerned, hear them as to the best manner of making the improvements, and prescribe the measures to be adopted for that purpose.

Sec. 45. They shall, according to the tenor of the petition and order of court, cause dams or dikes to be erected on the premises, at such places and in such manner as they direct; may order the land to be flowed thereby for such periods of each year as they deem most beneficial; and cause ditches to be opened on the premises, and obstructions in any rivers or streams leading therefrom to be removed; and they shall meet from time to time, as may be necessary, to cause the works to be completed according to their directions.

Sec. 46. They may employ suitable persons to erect the dams or dikes, or to perform the other work, under their direction, for such reasonable wages as they may agree upon; unless the proprietors do the same in such time and manner as the commissioners direct.

ORGANIZATION OF CORPORATIONS.

The procedure for the organization of corporations in this state is in accordance with the provisions of law as follows: Rev. Stats., Chap. 47; Pub. Laws, 1903, Chap. 235; Pub. Laws, 1905, Chaps. 85, 162, 171, 172; Pub. Laws, 1907, Chaps. 16, 71, 86, 109, 154, 172, 185.

Section 2 of Chapter 47 of the Revised Statutes has an important bearing on what follows regarding proposed legislation for the creation of drainage districts, and the state supervision of the construction of dams and control of reservoirs. The section in question is as follows:

Acts of incorporation, passed since March seventeen, eighteen hundred and thirty-one, may be amended, altered or repealed by the legislature, as if express provision therefor were made in

them, unless they contain an express limitation; but this section shall not deprive the courts of any power which they have at common law over a corporation or its officers.

PRESENT STATE SUPERVISION OF DAMS.

Section 43 of the Mill Act (Rev. Stats., 94) provides as follows:

> The governor, with the advice and consent of the council, shall annually appoint a competent and practical engineer, a citizen of the state, who shall hold said office until his successor is appointed and qualified, and who shall upon petition of ten resident taxpayers of any town or several towns, the selectmen or assessors of any town, or the county commissioners of any county, inspect any dam or reservoir located in such town or county, erected for the saving of water for manufacturing or other uses, and after personal examination and hearing the testimony of witnesses summoned for the purpose, he shall forthwith report to the governor his opinion of the safety and sufficiency thereof.

The paragraph above quoted was adopted in 1875. The next section provides that, in case the dam is reported as unsafe, the owners shall immediately repair same and in default thereof may be enjoined from the use of the dam, and the waters behind the dam may be discharged therefrom. When the dam is reported as safe the expenses of inspection shall be paid by the state, and when adjudged unsafe and insufficient, by the owner or occupant of the dam.

Since 1883 to the present time, nine separate accounts, totaling $260.57, have been paid by the state under the above provisions of law, and it is safe to assume that a less number of inspections, if any, have entered the decree of unsafe and insufficient.

The act creating the State Water Storage Commission was passed in 1909, Section 4 providing as follows:

> Every person, firm or corporation before commencing the erection of a dam for the purpose of developing any water-power in this state, or the creation or improvement of a water-storage basin or reservoir for the purpose of controlling the waters of any of the lakes or rivers of the state, shall file with said commission for its information and use copies of plans for the construction of any such dam or storage basin or reservoir and a statement giving the location, height and nature of the proposed dam and

appurtenant structures, and the estimated power to be developed thereby, and in case a dam is to be constructed solely for the purpose of water storage and not for the development of a water power at its site, plans and statements shall be filed with the commission showing the extent of the land to be flowed, the estimated number of cubic feet of water that may be stored and the estimated effect upon the flow of the stream or streams to be affected thereby. Every person, firm or corporation shall, as soon as practicable, after this act takes effect, file similar plans, reports and estimates in relation to any dam or storage basin or reservoir then in the process of construction by them.

There are no mandatory provisions compelling the filing of plans, and there is absolutely no mention of a state examination of the sufficiency of the design or provision for inspection during construction.

PROPOSED LEGISLATION.

From the confusion of a year or so ago, regarding the relationship of the public to quasi-public service companies and corporations, a method of procedure is slowly being evolved in the various states. It is largely taking the form of the appointment of public utilities commissions or of commissions with similar standings where, through their powers conferred upon them by legislative acts, the public have an intimate control of the affairs of corporations.

It is believed that some kind of control of Maine's water-powers and storage basins should be exercised by the state. Development of our water-powers is progressing, and the state should encourage every effort in this direction, but not to the detriment of its present or future interests. Concentration of water-power control and mergers of various companies have taken place during the past year in this state, and it is believed that public regulation is necessary. The entire subject is at present in a formative stage, and methods of procedure, policies, and ideas have not yet thoroughly crystallized. It is a matter for discussion and consideration by many minds.

A bill, introduced late in the session of the last legislature, 1911, having the approval of the chief engineer, provided for state regulation of water-power and water-storage companies. Pro-

vision was made for enlarging the powers of the State Water Storage Commission and placing the operations of the act under its direction. The measure in question was something entirely new in so far as this state was concerned, but it contained nothing that had not been adopted by one or the other of several states, including New York, Wisconsin, Pennsylvania, and Oregon. At the time given for the hearing of the bill before the legal affairs committee of the legislature, nearly all of the large water-power interests of the state were represented. The proponent of the measure realized that it was late in the session for adequate consideration of the various features of the bill and he therefore suggested to the committee that the bill be referred to the next legislature, which was done.

There is given below the text of the bill proposed by the chief engineer. It is somewhat modified from the proposed act that was referred to the 1913 legislature. The main intent of many of the features of the bill is to place the operations of water-storage and power-companies under an engineering commission. Many difficulties that now come before the legislative committees should be obviated through its operation. The following is a brief discussion of the various sections.

Section 1 empowers the State Water Storage Commission to divide the state into drainage districts by watershed lines for the purpose of creating administrative districts in order to carry out the provisions of the act.

The purpose is stated to be the state control and regulation of all great ponds of the state and all reservoirs created or hereafter created in part or in whole on any state lands or public lots. The section further authorizes the commission to mark, by permanent monuments, heights to which water may be raised or lowered on the reservoirs of the state, and further authorizes the commission to supervise the time and extent of the drawing of water from such reservoirs. Some such control is deemed necessary on account of the advantages that are given to various reservoir companies by later provisions of the act, especially Section 16, given below.

Exceptions have been taken to this latter provision as impairing existing contracts that the state has made with various water-storage companies through charters granted in the past. It is

believed that these objections cannot stand in the light of quotations given above; that is, the decision of the Supreme Judicial Court that the state owns great ponds and that the state has not lost the authority to control the waters of such great ponds; and the declaration of the Revised Statutes of Maine that all charters granted since 1831 may be amended, altered or repealed, by the legislature.

Section 1 places a restriction on the state commission by requiring it to regulate reservoirs under its control so that all water users shall derive the greatest benefit.

The section further provides that an appeal may be had from the decisions of the commission to a board of arbitration to consist of three hydraulic engineers to be appointed by a judge of the Supreme Judicial Court. The term "reservoir," as used in the bill, is defined as any storage basin having an available capacity of over 200 000 000 cu. ft. This provision was inserted in order that the state commission would be relieved of the operations of small reservoirs, especially those created by mill dams on the various rivers of the state. The 200 000 000 cu. ft. capacity is simply an arbitrary figure and might be changed if deemed advisable. This limiting capacity does not apply to reservoirs created on great ponds, as it is believed that the state should control all reservoirs on all the great ponds of the state.

Section 2 defines the term "concession" within the meaning of this act.

Section 3 declares what a public utility is within the meaning of the act.

Section 4 of the bill provides that the drainage districts created shall be in charge of district superintendents appointed by the commission through recommendation of the various water users of the district in question. This provides for the appointment of men intimately familiar with the basin, by the water users in that basin. The intent of this feature of the act is, that in case any of the water users are not satisfied with the acts of the district superintendents, appeal may be had to the state commission.

Section 5 provides that any engineers of, or members of, the state commission shall have free access to the buildings and grounds of water storage companies, shall have access to books, accounts,

and plans of such companies as are necessary for the purposes of the act.

Section 6 is an important section, giving authority to the state commission to pass upon and accept or reject any plan for dams constructed in the state.

The rejection of the plans is to be only on the grounds of the inadequacy of engineering features, and in this connection a board of arbitration is furthermore provided for. The grounds for this section are on account of public safety and of publicity. Up to the present time the state of Maine has not felt the need of suitable engineering supervision of plans for storage or power dams. The time has now arrived, however, when such supervision should be had on account of the construction of larger and higher structures of this nature.

Section 7 provides that certificates of incorporation of water-storage or water-power companies shall first be filed with the State Water Storage Commission before they are approved by the attorney-general. It further provides that such certificates shall designate the body of water that is proposed to be dammed.

Section 8 has a similar object in view as the preceding section, namely, that of publicity, in that no sale, assignment, etc., of any franchise of any corporation formed for the development of storage or water-power shall be valid until it has been filed with the Water Storage Commission.

Section 9 provides that the state of Maine may at any time in the future take over the physical properties of any corporations hereafter organized for the development of water storage in the state. This is the usual provision now inserted in legislative charters for large water storage or power companies.

Section 10 provides that time limit for all concessions granted under terms of this act shall be from twenty-five to sixty years, the period of termination being determined by the State Water Storage Commission at the time of the approval of the concession. Provision is also made for possible extension of the charter.

Section 11 provides for an annual tax on the gross receipts of all water-power companies. The first draft of this section contemplated an annual tax or rental based on the horse-power developed, with provision for deduction on account of transmission

losses. However, there is an objection to this method in that the man that sells his power at a lower rate is taxed higher than one who sells his power at a higher rate. To overcome this inequality the tax is to be assessed on a percentage of the gross receipts. Provision is made for the tax being assessed on a sliding scale.

Section 12 provides a penalty for non-payment of taxes.

Section 13 requires the keeping of such accounts and records as the commission deems necessary.

Section 14 provides that whenever the owner of any dam desires to take or overflow any land, he shall apply to the commission for the approval of his request, and whenever said approval is given, right of eminent domain may be exercised under the so-called mill act.

Section 15 provides that whenever the owner of any concession that has received the approval of the State Water Storage Commission desires to overflow any great pond or any public lots or state lands, application shall be made to the Water Storage Commission. The said commission is then to make an engineering investigation of the matter and report to the next legislature results of its investigations, together with its recommendations.

Section 16 provides for the reimbursement to persons or companies who make expenditures in the creation or improvement of storage reservoirs. Such owners shall be paid by the state of Maine all reasonable costs of operation and maintenance and a net annual return for twenty years of five per cent. of the cash spent in creating, improving, or increasing storage. Furthermore, all water users below, who are benefited by such increase, shall pay their proportionate share of the cost of operation and maintenance of the reservoirs and their proportional amount of the net annual return for twenty years of five per cent. of the money invested. In other words, if a person or company goes to the expense of creating, increasing, or improving storage, they are reimbursed by all the water users on the stream benefited thereby.

Section 17 provides for the installation of suitable and accurate meters and other instruments adequate for the measurement of electrical energy generated by any person, firm, or corporation in the state, and also provides for a penalty in case such meters are not installed within a prescribed limit of time. The commission

is given power, however, to extend the time in which the installation must be made before the penalty attaches.

A circular letter was sent to the various light and power companies in the state, requesting them to report, among other matters, the total annual output of the generators in kilowatt hours. Answers to this question were meager, and in many cases where figures were given they were estimated. This is generally due to the fact that many companies, especially smaller ones, have no measuring devices for recording the total annual output in kilowatt hours of generating stations. It will not be many years before a Public Utilities Commission is created by statute in this state, and answers to the questions on the form will be required by that commission.

Section 18 provides for an appeal to the Supreme Judicial Court against any decisions of the State Water Storage Commission.

Drainage District Act.

The bill in question is as follows:

An Act for the creation of drainage districts, the supervision of the construction of dams, and the control and regulation of storage reservoirs.

Be it enacted by the People of the State of Maine, as follows:

Section 1. The State Water Storage Commission is hereby authorized and empowered to divide the state into drainage districts by watershed lines for the purpose of controlling and regulating all great ponds of the state and all reservoirs created or hereafter created in part or in whole on any state lands or public lots of the state; and said commission is hereby authorized and empowered to mark by permanent monuments and bench marks the heights to which water may be raised or lowered on the great ponds of the state and on all reservoirs created or hereafter created on any state lands or public lots of the state; and, furthermore, the said commission is hereby authorized and empowered to supervise and control the times and extent of the drawing of water from all great ponds and from the reservoirs created or hereafter created on any state lands or public lots of the state.

All reservoirs under the supervision and control of the State Water Storage Commission shall be regulated by said commission so that all the water users shall derive the greatest benefit.

Provided, however, that if any water user feels himself aggrieved

as to the manner of said regulation, he may appeal to a board of arbitration to consist of three hydraulic engineers to be appointed by a judge of the Supreme Judicial Court, the cost of said arbitration to be paid by the party requesting the arbitration.

The term reservoir, as used in this section, shall mean any storage basin having an available capacity of over 200 000 000 cubic feet, provided, however, that this limiting capacity shall not apply to any reservoir created on any great pond of the state.

Section 2. The term "concession" as used in this act shall mean and embrace every certificate issued by the state through the State Water Storage Commission in its approval of any plans and statements filed with it in accordance with the provisions of section 6 of this act, or of every certificate issued by the said commission as provided for in sections 7, 8, and 14 of this act.

Section 3. Every person, firm, or corporation, their heirs, executors, administrators, successors, assigns, lessees, trustees, or receivers appointed by any court whatsoever, who accepts, takes and holds a concession for the erection and operation of a water storage reservoir under the provisions of this act, is hereby declared a public utility.

Section 4. The drainage districts created under the provisions of section one of this act shall be in charge of district superintendents who shall report to and receive their instructions from the chief engineer of the State Water Storage Commission. Said district superintendents shall be appointed by the State Water Storage Commission from lists of persons recommended by the water users, including the log-driving associations, the water power users and the dam and reservoir owners of the respective drainage districts. Provided, that one district superintendent may have charge of more than one drainage district.

Section 5. For the purpose of carrying out the provisions of this act, or for any other lawful purpose, the State Water Storage Commission, the chief engineer, or any other engineer, or other person appointed by said commission for that purpose, shall have free access to all parts of the buildings, structures or grounds utilized by the owner or owners of any concession granted under the terms of this act, and may take any measurements and observations, and may have access to and copy from, all books, accounts, plans and records of said owner or owners, as are necessary for the purposes of this act.

Section 6. Every person, firm, or corporation, before commencing the erection of a dam, or the enlargement of any existing dam, for the purpose of developing any water power in this state, or the creation or improvement of a water storage basin or reservoir for the purpose of controlling the waters of any of the great ponds or rivers of the state, shall file with the State Water Storage

Commission for its information and use, copies of plans for the construction of any such dam or storage basin or reservoir, and a statement giving the location, height and nature of the proposed dam and appurtenant structures and the estimated power to be developed thereby and also the name of the river, stream, lake, pond, or other body of water from which it is proposed to use water power, or on which it is proposed to store water, and as near as may be, the points on said river, stream, lake, pond, or other body of water, between which said water power or storage of water is proposed to be taken or used or developed, and such other information as said commission may require, and until said plans and statements are filed with and have received the approval of a majority of the members of said commission, and until a certificate to this effect has been issued, and the concession granted, it shall be unlawful to start construction on any such said dam or dams or appurtenant structures; and, furthermore, it shall be unlawful to change or modify any such plans or any designs until the changes and modifications have received the approval of a majority of the members of said commission, and until a certificate to this effect has been issued and the concession granted; provided, however, that the rejection of any plan or plans shall be on the ground of the inadequacy of the engineering features of the plans, unless a great pond or state land or public lot or lots are involved; and provided, further, that in case of the rejection of plan or plans on account of inadequacy of the engineering features, recourse may be had to a board of arbitration as provided for in section one. Every person, firm, or corporation shall, as soon as practicable, after this act takes effect, file similar plans, reports and estimates in relation to any dam or storage basin or reservoir then in process of construction by them.

Section 7. No certificate of incorporation, among the purposes of which are the development of water storage or water power in this state, shall be approved by the attorney-general unless said certificate is first filed with the State Water Storage Commission; nor unless said certificate of incorporation shall contain, in addition to the statements now required to be made, the name of the river, stream, lake, pond, or other body of water from which it is proposed to use water power, or on which it is proposed to store water, and, as near as may be, the points on said river, stream, lake, pond, or other body of water, between which said water power or storage of water is proposed to be taken or used or developed, and such other information as said commission may require; nor until a certificate to this effect has been issued by the State Water Storage Commission and the concession granted.

Section 8. No sale, assignment, disposition, transfer, or conveyance of the franchises, and all the property, real, personal, and

mixed, of any person or firm engaged in the development of water storage or water power in this state, or of any corporation heretofore or hereafter formed, for the development of water storage or water power in this state, to any other such corporation or to any person or firm, shall be valid until a certificate, prepared and duly executed by the president and secretary of the corporation so purchasing, under the seal of said corporation, or by such person or firm designating the river, stream, lake, pond, or other body of water, and as near as may be, the points on the said river, stream, lake, pond, or other body of water, between which said water power or storage of water is proposed to be taken, or used, or developed, and such other information as the State Water Storage Commission may require, has been filed with the said commission; nor until a certificate to this effect has been issued by the State Water Storage Commission and the concession granted.

Section 9. All the property, rights, and franchises within the state of Maine acquired, erected, owned, held or controlled by any corporation, hereafter organized for the development of water storage in this state, or its successors or assigns, at any time after this act shall take effect, under and by virtue of the terms thereof, shall be subject to be taken over by, and become the property of the state of Maine, whenever said state shall determine by appropriate legislation that the public interests require the same to be done. Upon the taking effect of such legislation, the ownership of said property, rights, and franchises shall immediately be transferred to, and vested in, said state of Maine, and said state shall pay to the owner or owners thereof, the fair value of all the same, excepting, however, such franchises and rights as are conferred upon any said corporations under and by virtue of the provisions of any legislative act or acts or any special charter or charters owned or controlled by any said corporations, which said franchises and rights shall be wholly excluded in the determination of the amount to be paid to any said corporations by said state of Maine. Provided, that should the state proceed under this section, it shall assume the contracts of the company or companies whose property it takes.

The fair value of the property, rights, and franchises so taken by the state of Maine, subject to the exceptions hereinbefore mentioned, shall be determined by agreement between any said corporations and such officers and agents of said state as shall be thereunto authorized to act in its behalf by the act which authorizes the taking of said property, rights, and franchises; and such agreement failing within six months after said act takes effect, then by such fair and impartial tribunal and under such provisions as to the manner of procedure and for full hearing of

parties and payment of damages awarded as shall be provided in said act.

Section 10. Any concession granted under the terms of this act shall terminate within a period of from twenty-five to sixty years from the date of approval of the concession, unless earlier taken over by the state under the provisions of section seven of this act, the period of termination being determined by the State Water Storage Commission at the time of their approval of the concession in question.

At the expiration or earlier termination of any concession, all rights under the concession shall revert to and become the property of the state upon the state making just compensation for the physical property to the person, firm, or corporation, in accordance with the provisions of section nine of this act; provided, however, that the State Water Storage Commission may extend the concession under the terms of this act, and if the holder of any such concession, during the term thereof, has complied with all the laws and regulations, said holder shall have a preference right to renew the concession on reasonable terms laid down by the commission, and in case said holder declines to accept the new concession, the State Water Storage Commission shall elect whether the state shall take over the physical property in accordance with the provisions of section nine of this act, or whether it shall grant another concession, in which case the original concessioner shall have the privilege of selling or disposing of his buildings and machinery to his successor in concession.

Section 11. Every person, firm, or corporation, except municipal corporations, engaged in the development of water power, shall, in lieu of all other forms of state taxation, pay to the state of Maine an annual tax on or before the second day of January of each year, of not less than one half of one per cent. or not more than five per cent. of the gross annual income of said person, firm, or corporation, or if the power is used by the owner and not sold, the annual tax shall be at the above mentioned rates but based on an appraisal of the value of said power as determined by the State Water Storage Commission; provided, that, in the case of a disagreement on said appraisal, recourse may be had to a board of arbitration as provided for in section one. The rate of taxation may be on a sliding scale but shall be fixed by the State Water Storage Commission. The said commission may also determine at what future dates the rates may be readjusted within the above limits.

Section 12. If any person, firm, or corporation shall fail to pay the annual franchise tax as provided for in section ten of this act within ninety days after the same is due and payable, the state shall have a preference lien therefor, prior to all other liens or

claims, upon all the property of said person, firm, or corporation and upon notice from the State Water Storage Commission the attorney-general shall proceed to enforce the lien and collect any unpaid fees in the same manner as other liens on property are enforced.

Section 13. It shall be the duty of every person, firm, or corporation granted a concession under the terms of this act, to keep such accounts and records as may be required by the State Water Storage Commission, and to report the same together with such other information over affidavit, as may be required by said commission on suitable blanks to be furnished by the commission and at such times and dates as may be specified by said commission. The failure upon the part of any said person, firm, or corporation to comply with the provisions of this section shall be deemed a substantial non-compliance with the provisions of this act, and of the concession granted to such person, firm or corporation.

Section 14. Whenever the owner or owners of any dam or dams used for the purpose of developing water power in this state, or the creation or improvement of any water storage basin or reservoir, find that, for the purpose of creating, acquiring, maintaining and operating their dam or dams and other works, it is necessary to overflow certain lands, said owner or owners shall apply to the State Water Storage Commission for the right to take and use any lands, riparian or other rights, that may be required for the creation, construction and maintenance of any and all reservoirs, dams, and other structures and improvements that may be necessary to accomplish the purposes of their charter, and after the approval of the majority of the members of the State Water Storage Commission has been given and a certificate has been issued stating that said commission does approve the taking or overflow for the particular purpose stated, then and not until then, the said owner or owners of the said dam or dams may proceed to exercise the right of eminent domain for the particular purposes stated in accordance with the provisions of Chapter 94 of the Revised Statutes and laws amendatory and supplementary thereto; provided, however, that the rejection of the application for the said taking or overflow shall be on the ground of the inadequacy of the engineering features of the plans, unless a great pond or state land or public lot or lots are involved; and provided, further, that in the case of the rejection of the said application for the said taking or overflow on the ground of the inadequacy of the engineering features, recourse may be had to a board of arbitration as provided for in section one.

Section 15. Whenever any person, firm or corporation contemplating the erection or the enlargement of any dam or dams for the purpose of developing water power in this state, or the creation

or improvement of any water storage basin or reservoir, find, that for the purpose of creating, acquiring, maintaining, and operating their dam or dams and other works, it is necessary to overflow any great pond or take or overflow any public lot, lots or state lands, said owner or owners shall apply to the State Water Storage Commission for such rights of taking or overflow.

The said commission may make an engineering investigation of the desirability or necessity of such taking or overflow, and report to the next legislature the results of its investigations together with its recommendations for or against the said taking or overflow and include in said report its estimates of damages if any state land or public lot or lots are involved.

Section 16. In case the owner or owners of any dam or dams used for the purpose of developing water power in this state, or the creation or improvement of any water storage basin or reservoir, shall create, improve or increase storage on any great pond or any reservoir created for the storage of water, said owner or owners shall be entitled to be reimbursed by the treasurer of the state of Maine on warrants drawn and approved by the Governor with the advice and consent of the Council for all reasonable costs of operation and maintenance and a net annual return for twenty years of five per cent. on the cash actually spent in creating, improving, or increasing said storage. All owners or lessees of each and every improved water power operated for over eight months in the year, located below said reservoir or reservoirs or storage basin or basins and benefited thereby, shall pay into the treasury of the state of Maine his or their proportionate share of all the reasonable costs of operation and maintenance and a net annual return for twenty years of five per cent. on the cash actually spent in creating, improving, or increasing said storage, including the cost to the state of the supervision and regulation of said reservoir or reservoirs or storage basin or basins. The apportionment of the said reasonable costs and the said annual return of five per cent. shall be made by the State Water Storage Commission in proportion to the resulting benefits.

If any said owner or lessee of any improved and operated water power fail to pay his or their proportionate share of all the reasonable costs of operation and maintenance and a net annual return of five per cent. on the cash actually spent in creating, improving, or increasing storage from which they are benefited, within ninety days after the same is due and payable, the state shall have a preference lien therefor, prior to other liens or claims, except for taxes, upon all the property of said owner or lessee, and upon notice from the State Water Storage Commission, the attorney-general shall proceed to enforce the lien and collect any unpaid fees in the same manner as other liens on property are enforced.

Section 17. Every person, firm, or corporation engaged in the generation of electric current in this state shall install, within three months of the date of approval of this act, suitable and accurate meters and other instruments approved by the State Water Storage Commission, adequate for the measurement of the electric energy generated, and such person, firm, or corporation shall keep accurate and sufficient records showing the quantity of electric energy generated each day in the year and the number of hours run per day, and report same to the State Water Storage Commission on blanks prescribed by, and at such time as shall be determined by, said commission; provided, that in case any person, firm, or corporation engaged in the generation of electric current in this state fails to install suitable and accurate meters and other instruments within the time above specified, such person, firm, or corporation shall be subject to a penalty of $10 per day for each and every day over the above limit of three months, during which they have not made the necessary installation, said penalty or penalties to be paid into the treasury of the state of Maine; and provided further, that the State Water Storage Commission may extend the time before the penalty attaches in which to install the suitable and accurate meters and other instruments.

Section 18. Any party, feeling himself aggrieved by any act done, or failure to act, or by any findings or rulings made by the State Water Storage Commission, subsequent to the granting and acceptance of the concession as provided in this act, shall have the right to appeal to the Supreme Judicial Court in the county in which its dam is located, or at its option in Kennebec County.

CONTENTS.

CITATIONS.

DISCUSSION.

MR. MORRIS KNOWLES.* I have been interested in the change of view between what has been and what is proposed, in the new Conservation Act now being recommended in the state of California. It is now planned to place in the control of one body of five men versed in various classes of conservation, the duties and authority formerly residing in the Board of Forestry, Redwood Park Commission, Fish and Game Commission, Water Commission, and present Conservation Commission. The duties of these boards are to be conferred upon the new board with broader powers and privileges.

I desire, however, to speak particularly at this time of the necessity of some legislation in our states that will promote development of the water resources by private capital under reasonable regulation; so as to prevent exploitation and secure at the same time to the people such desirable benefits as come from regulation of stream-flow; the prevention of floods, dilution of pollution, better navigable stages, as well as others that will be obtained when we have state-wide regulation. This is the reason for the formation of the new organization in our state, called the Water Conservation Association of Pennsylvania, of which I have the honor to be president.

A group of capitalists and publicists, realizing the good to come from a common meeting ground to discuss these problems of vital importance to investors and the people, met to consider this question, and formed this unique organization in which many minds are represented upon the executive committee. It is planned to conduct a state-wide campaign of publicity and education; with the expectation of thus securing, by coöperative effort, certain legislation at the next session of the state legislature which will bring order out of chaos as to water laws (the right of eminent domain as to appropriation of water, under-lands, and rights of ways does not exist with companies formed since 1905), to attract capital to develop the state's water resources; — but, at the same time, reserve to some tribunal the review of the exercise of the right of eminent domain and not only supervise the design and

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construction of dams (as recommended by Mr. Chandler and Professor McKibben), but also the operation thereof, so as to prevent floods and secure regulation of stream-flow.

I have been much impressed with Mr. Babb's well-thought-out plan of procedure, as explained in his paper; but, perhaps because our customs may not be the same as in Maine or because we have not yet given so much consideration to the subject, some few of the provisions suggested seem to be, upon first reading, either conflicting or unnecessary, in the light of the modern development of the true idea of conservation. While the speaker wishes to express the strongest agreement with certain parts of the paper, he would like to ask, without any spirit of antagonistic criticism, but with the attitude of inquiry, questions about certain clauses.

Section 1. The provisions in the second paragraph of this section — relating to the control over the uses of water, that the greatest benefits shall be derived therefrom for all users — are excellent and directly in line with the principles advocated by the Pittsburgh Flood Commission, and they have recently been incorporated in two charters lately granted by the Water Supply Commission of the state of Pennsylvania.

Section 4. The provision herein stated that district superintendents shall be appointed from lists of persons, recommended by various water users, — such as log-driving associations, reservoir, dam, and power owners, — is a recognition of the point of view, not to say the rights, of the practical operator, which is only too often forgotten in such legislation.

Section 6. The provision that copies of plans, showing design and location and nature of proposed work and structures, shall be filed and then "receive the approval of the majority of the members of the said commission" is just what Professor McKibben has been advocating and is much better than the Connecticut system, where any one member of the commission may approve.

Section 9. The arrangement for a purchase by the state, herein mentioned, is extremely vague, and it is difficult to imagine what may be meant by "*such franchises and rights*," other than those conferred by the acts of the legislature, and the condition seems

still more complicated by the statement in the second paragraph of Section 10, that just compensation shall be made for the "*physical property*." If it is intended to mean by these terms that there shall not be any value, other than that of the physical property, as properly determined, allowing nothing for "development, expense," or "business value," it hardly seems that the provisions are fair to the investor of capital, which must stand early losses.

Section 10. If there be the right of purchase, as provided in Section 9, is there any need of the concession terminating at the end of twenty-five to sixty years, especially if there be a provision for the regulation of rates to be charged to the public? Earlier in the act, in Section 3, such business is declared a "*Public Utility*," and it may be that some public utility law, not herein mentioned, provides for such rate regulation, but, in the absence of definite statement, we are not sure about this and it will be well if it can be cleared up. Does not the last provision of this same section permit of indefiniteness of construction and also permit a chance of a "hold-up" of the company whose franchise is expiring, or force it to sell out at a sacrifice to the company which secures the new franchise?

Section 11. An interesting query is raised with regard to this section, that if rates should be regulated, why should it be necessary to charge a tax upon the power company, either in proportion to the power developed or as a percentage of the gross receipts? With proper state regulation, such expense of course must be borne by the rate payer, but assuming it to be fair, is there any reason why municipal corporations which develop power should not be similarly taxed? Are they not doing a commercial and not a municipal business in such a case?

Section 14. The provision for a review of the exercises of the right of eminent domain is directly in line with what is now proposed in Pennsylvania, but the more cumbersome provisions of Section 15, which means going to the legislature for action, can hardly be as satisfactory.

Section 16. The provisions herein listed are much like the arrangements of the *Genossenschaft* of Europe, namely, "Associations not for profit," which bring about the coöperative effort of Capital, State, and People, in securing profits from investments

and great benefits. It will be very desirable if we secure some such legislation in this country.

There was one additional thing that Mr. Babb mentioned in closing which seems to me important, namely, that some of the penalties or punishments were not included in the bill with the idea that if they were perhaps the bill would not pass. The oft-repeated statement occurred to me in that connection, that it is not so much the punishment or severity of the punishment which is necessary as it is the certainty. I think in matters of this sort definiteness as to what is required is far better than indefiniteness, although it may have been thought to have been necessary to do some trading in order to get the thing through the legislature. I think it is extremely unfortunate, however, if they thought it necessary to do anything which might be a compromise rather than to have something which would be definite and which everybody could understand.

Mr. P. P. Wells.* I have listened to Mr. Babb's paper with very great interest as an evidence that the conservation movement has taken root in New England. Having been connected with it here in Washington for the past five or six years I am much interested in seeing it taken up in the section from which I come. I was glad to note, in looking over Mr. Babb's paper, the forethought with which the founders of the state of Maine and the state of Massachusetts had retained to the state the control of the "great ponds." It gives the state a grip on the situation that is lacking in southern New England so far as I know; and, also, I suppose there are still considerable holdings of public land in the state of Maine, which we have not in southern New England, and which again give the state jurisdiction like the jurisdiction which the Federal Government has in the West, where it is a landowner to such a large extent throughout the mountain region.

I particularly noted two or three matters mentioned in Mr. Babb's paper. One of them is the matter of the time limit of the franchise, which Mr. Knowles called attention to. Theoretically I agree with Mr. Knowles's suggestion that if you have competent regulation and competent provision for the public taking over

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by buying out any private enterprise of this kind on fair terms, no time limit is necessary. But such provisions are rather uncommon. I believe the state of Wisconsin in its public utility policy goes upon the principle that franchises are indeterminate, and that the state may purchase at a valuation based primarily upon the construction cost, or replacement cost, with due allowance for promotion costs and other legitimate expenses. I think in the present state of development of public opinion in most of our commonwealths the time limit is a valuable element in any legislation of this kind, because it serves to protect the public until such time as a more perfect system of regulation can be worked out after the Wisconsin system, and because it will automatically bring up to the public at some future day the question as to what the public interest demands with respect to the expiring franchises.

I was also particularly interested in the matter of the provisions in this proposed Maine bill for forcing contribution to the cost of storage. That matter has come under my attention a good deal with respect to operations where the Federal Government was concerned. We have had cases in the West where on certain streams storage was to be put in by one company and others would get the advantage of it, and it is perfectly obvious that equity demands a contribution on the part of the companies who get the advantage of the investment, who at present do not contribute to it.

In regard to state purchase, — I have already alluded to the right of the state to purchase, — it seems to me that that is a very valuble suggestion — perhaps not worked out fully in detail, and it is probably impossible to so work it out at this time.

I have heard what Mr. Knowles has said about the regulation of prices and of service by the state, and it seems to me that that is one of the most important things for the state to do at this time, — that where the state has jurisdiction because state assistance is necessary in the way of corporate charters, or in the way of the use of state lands or the use of these great ponds or otherwise, under those circumstances there should be a strict regulation by the state in the public interest of the service to be rendered and the prices to be charged.

I have given some attention to the control of water power since the year 1907, in several different capacities, so far as the

Federal Government is concerned, — first, in connection with the Forest Service, of which I was the law officer until 1909; and contemporaneously with that giving informal advice and assistance to the Power Committee of the Inland Waterways Commission, which was created by President Roosevelt in 1907; and then for more than a year as counsel for the National Conservation Association; and for the past year in the office of the Secretary of the Interior, so perhaps it would not be out of the way for me to briefly state here the water-power control problem from the point of view of the Federal Government.

The Federal Government has or claims jurisdiction over water power from two different sources: In the first place, as a landowner. Throughout the West, the Rocky Mountain and Pacific states, the United States is the principal landowner, and has in its ownership a large number of power sites. Pretty much all the undeveloped water power out there is in federal ownership. As landowner, the consent of the United States must be secured to any water-power development there. Some of that land is in National Forests, and the rest of it is for this purpose under the jurisdiction of the Secretary of the Interior. In either case the water-power development is regulated under an act passed February 15, 1901, which compels a person wishing to develop a power to come to the Federal Government and get a permit from the Secretary of Agriculture if it is in a national forest, or from the Secretary of the Interior if it is outside such limits. Now, until the administration of the national forests was transferred to the Secretary of Agriculture, by an act passed February 1, 1905, there was no attempt at what may be fairly called public regulation under this statute. When the jurisdiction was transferred, the Forest Service took up the problem of water-power control and worked it over with the companies, with the applicants for permits, and adopted regulations which were changed with experience, as necessity showed was expedient, until the result was regulations which are embodied in what is called the "Use Book" of the Forest Service concerning water power, and which can be procured by application to the forester, — a series of comprehensive regulations on the subject.

The Interior Department has never until very recently attempted

any thorough-going regulation under that statute, but on the 24th of last month regulations were issued by the Secretary of the Interior, which are very much like the Forest Service regulations, and which do attempt regulation of this character. I would say briefly about these that they provide for a rental charge to the government for the use of government land and for a time limit of fifty years, or not more than fifty years, for the privilege. In that connection I want to say that the great defect of this statute is that every privilege given by it is expressly by the statute made revocable by the head of the department, and that for the past five years the administrative branch of the government has been recommending legislation to allow the issuance of permits which would be irrevocable for fifty years. We have not succeeded in getting that legislation, which is so essential to safety for the capitalists who invest; but in these regulations both departments have gone to the limit of their powers by indicating, as far as they can, that the intent is that the permit shall remain in force for fifty years. But of course no secretary can bind his successor in that behalf, in view of the express language of the statute. Then in these recent regulations by the Secretary of the Interior there is a provision for purchase by the Federal Government, by the state, or by any municipality, at a fair value, with a bonus of three fourths of one per cent. for every year of the unexpired term. That is, if there were twelve years of the fifty yet to run, we would ascertain the fair physical value of the works and add nine per cent., and the public could buy them at that rate. Also by these regulations the grantee is bound to submit to reasonable regulation of prices and service by the duly constituted authority of the state in which the service is rendered. Also the rentals may be readjusted by the department at the end of ten-year periods. I think perhaps it will be interesting to read that particular provision:

"At any time not less than ten years after the issuance of final permit and after the last revision of rates of rental charge thereunder, the Secretary may review such rates and impose such new rates as he may decide to be reasonable and proper; *Provided*, that such rates shall not be so increased as to reduce the margin of income from the project over estimated and proper expenses (including reasonable allowance for repairs and renewals) to an

amount which, in view of all the circumstances (including fair promotion costs and working capital) and risks of the enterprise (including obsolescence), is unreasonably small, but the burden of proving such unreasonableness shall rest upon the permittee."

Now, under the terms of this statute it is impossible to give jurisdiction to the courts in such a matter. These questions as to what is reasonable and proper must, therefore, be decided by the Secretary. The desirable arrangement would be to have the decisions as to what is fair rental, and the reasonableness of these various items, passed upon by the courts, and it is hoped that we will get legislation from Congress which will authorize such an arrangement.

There is another basis for the federal policy of water-power control which I will briefly mention, and that exists where navigable streams are concerned. I have scrutinized, I think, every bill introduced in Congress since the fall of 1907 granting licenses for the damming of navigable streams. There has been a legal contest waged around the question whether the Federal Government has any right to attempt any control in such cases, but after a good deal of hesitation and difference of opinion on the part of the government officers, the policy has been established by this administration — and I may say it was established by the preceding administration — of refusing such a license without express provision for regulation of this kind, — the requirement of a rental charge and provisions to protect the consumers of the power. In pursuance of that policy, bills granting such licenses, which did not contain those requirements provisions, have been vetoed during the past session of Congress.

Prof. Philander Betts.* This suggested bill apparently assumes the enactment shortly of a bill providing for a Public Utilities Commission. In connection with the definition of a public utility given in Section 3 of this suggested act, I want to state the experience of the New Jersey Commission. A public utility in New Jersey is defined by the Public Utilities Act in such a way that municipalities or municipal corporations are not included. Complaints have been made to the board at various times regarding the service furnished by municipalities, and the

*Chief Engineer of the New Jersey Public Utilities Commission.

board has been powerless to entertain complaints of that kind. It seems absurd that in exercising regulation over public utilities such regulation can only extend to privately owned utilities, — utilities operated by means of capital furnished by private individuals. It seems to me that such regulation, if regulation is justified, and to-day we consider that it is, is justified because of the character of the services themselves. These services are public utilities, and therefore should be subject to regulation. The Wisconsin law clearly recognizes this by making no difference as to who operates the public utility, whether it is operated by a private corporation or by a municipal corporation. I would make the suggestion, therefore, that this proposed bill ought to be amended, if possible, so as to include public utilities, no matter who operates them.

Another suggestion is in regard to the clause limiting the term of the franchise. A good deal has been said in the last few years regarding the terms of franchises. In years gone by, many franchises and charters had no limits, and the tendency at the present time with municipal corporations is to go to the other extreme and to limit the term in which the franchise may be exercised to a period too short to justify a company in making the investment to furnish a proper service. I would commend for consideration by every one interested in operation of plants, as well as by those interested in the enactment of public utility laws, the provision of the Wisconsin law for an intermediate permit, or for a permit unlimited during good behavior. All franchises for a definite term ought to include some provision for the period following the termination of the franchise. If this is not done, and there is any uncertainty with regard to the ability to obtain a renewal of the franchise, the temptation on the part of the company will be to stint the service and to withhold the expenditures of money required in making extensions and in keeping the service itself up to the point of adequacy.

Mr. M. O. Leighton.* Mr. Babb in his paper has admirably covered a difficult field. He has quoted a large number of court decisions relative to water rights, and they are very instructive. They are instructive largely because they reveal many difficulties

* Chief Hydrographer, United States Geological Survey.

and absurdities. I shall surely be criticised when I state that the greater part of our difficulties in the eastern part of this country arises from the fact that we are governed by one of the most abominable of our abominably revered institutions, namely, the riparian law. When we have jockeyed about to our satisfaction and have become convinced that water is the property of the whole people and must rationally be devoted to the highest use without regard to precedent, we will abrogate the riparian law and the entire principle underlying it. It will be very difficult to accomplish such a purpose because of our conservatism with reference to changes in fundamental law.

Our friends in the legal profession are always prone to regard the law as the end rather than the means. Their habits of mind are not unlike that of the miser who is gloating over his gold. His attention is fixed on the gold, not as a medium of exchange, but as a mere substance, the presence of which gives him satisfaction. In like manner we are prone to consider the law, not as a means to an end, not as a servant created to assist us in realizing our needs and desires in the wisest way, but as a final and unchangeable institution, to which we must bow and worship. Of course, I am now referring to fundamental law which lies at the basis of all our jurisprudence. I am unable to understand why we should be expected to direct all our constructive procedure according to the precedents established by the law of an earlier day and at the same time be considered unprogressive should we endeavor to utilize old methods of transportation in the conduct of modern business.

My point will be illustrated by quoting from one court decision cited by Mr. Babb. The case was evidently one in which complaint was made that a dam obstructed the use of a river for log-driving purposes. The judge instructed the jury that if the river in its natural state was capable of being useful for floating boats, logs, etc., for purposes of trade or agriculture, the plaintiff was entitled to recover however long the dam of the defendant might have stood and notwithstanding his use of the river had been open, notorious, and adverse, and although no logs had ever been floated over the falls where the dam now is. (Knox *v.* Challoner, 42 Maine, 150.) The merits of this particular case are of no

immediate importance, but I would like to call your attention to the fact that here is a decision — and there are many others — which establishes the principle that the prior use of this river must be for navigation purposes, or log-driving purposes, irrespective of the facts and merits in the case. No matter how detrimental this prescribed prior right might be to the community, no matter how many people might be injured, or how insignificant was the log-driving use, that use is prior to all others merely because under the conditions which prevailed in an earlier day, navigation was considered paramount. Why should this be so?

Another illustration may be given. In those cases in which adverse decision has been made on the principle of compensation in kind, does it not appear absurd that a riparian owner can enforce his right to have a river flow by his property in its natural condition and be entitled to recover damages even though a corrected condition — brought about, for example by the construction of a reservoir — makes the river more valuable to him than it was before? In the state of California a great fertile valley is throttled in its development because of just such a decision.

Having observed closely the principle of prior appropriation based on beneficial use which prevails in the most of our western states, I cannot fail to recognize its superiority. It may be instructive to consider one of the state's laws based on this principle. Let us choose for convenience the law of Oregon. The act providing for the granting of franchises of water power begins as follows:

"All water within the state from all sources of water supply belong to the public."

Section 45 of the Oregon water law reads as follows:

"*Application.* — Any person, association, or corporation hereafter intending to acquire the right to the beneficial use of any waters shall, before commencing the construction, enlargement, or extension of any ditch, canal, or other distributing or controlling works, or performing any work in connection with said construction, or proposed appropriation, make an application to the state engineer for a permit to make such appropriation. Any person who shall wilfully divert or use water to the detriment of others without compliance with law shall be deemed guilty of a mis-

demeanor. The possession or use of water, except when a right of use is acquired in accordance with law, shall be *prima facie* evidence of the guilt of the person using it."

The Oregon law goes further. Should you have what would be considered in the East a riparian right and desire to develop a water-power privilege existing on your own land, and should you in conformity with the Oregon law apply for a permit to use the water and be granted the same, you cannot congratulate yourself that you have a permanent right. Section 53 of the Oregon law reads:

"*Water-right Certificate.* — Upon it being made to appear to the satisfaction of the board of control that any appropriation has been perfected in accordance with the provisions of this act, it shall be the duty of the board of control to issue to the applicant a certificate of the same character as that described in Section 25. Said certificate shall be recorded and transmitted to the applicant, as provided in said section. Certificates issued for rights to the use of water for power development acquired under the provisions of this act shall limit the right or franchise to a period of forty years from date of application, subject to a preference right of renewal under the laws existing at the date of expiration of such franchise or right."

The appropriation of water under such a statute is based entirely on beneficial use. No right is granted for a larger amount of water than can be beneficially used for the purpose for which it is desired. With such a fundamental principle established in the East, it would be impossible to sustain a water right which was not conducive to the best interests of the people as a whole; it would be impossible to use the common law as a basis and pretext for petty blackmail as is now done, the power developer and investor would benefit by the assurance of stability given under the law, and the people as a whole would be assured of maximum benefits resulting from the wisest use of their water resources. Such a change will not probably be made for several generations, but it is sure to prevail eventually.

Mr. Cyrus C. Babb (*by letter*). The writer considers himself fortunate that he was able to be present at the conference, as a number of valuable suggestions were received from the various

papers and their discussion. Consideration has been given from time to time to the several points raised by Mr. Knowles. In fact, most of the provisions of the entire bill have been rewritten a number of times. Section 9 is the usual form now inserted in legislative charters for large water storage or power companies, except modified to fit general conditions. This section, as well as the second paragraph in the next section, has been troublesome to write. It is not intended to exclude development expense, but to pay the "fair value," excluding, however, franchise value, which is used in its narrow meaning, that is, the intangible value of the franchise or right granted by the legislature. It is the people that grant the franchise, and it is believed that when they purchase the plant, they should not pay for a right that they granted in the first place.

The term "physical property" in the second paragraph of Section 10 was an error. It should have been the fair value of the property with the franchise value excluded. Probably the last provision can be made clearer. The intent is to give the holder of the original concession the preference right to renew. If he declines, allow the state to purchase, but if the state is not ready for such action, provide for its purchase by a third party.

The writer has had under consideration the "indeterminate franchise" as recognized by the Wisconsin Commission, but he wishes to understand the practical workings of it before adoption. At the present moment a limited franchise or concession seems to safeguard better the public's interest. Sixty years hence, our idea of the value of water power may be changed from what it is now.

Section 11: The tax on water power is a special tax from which it is believed the state should receive a revenue. It will not be so heavy — varying, on a valuation of $20 per horse-power, from 10 c. to $1.00 per horse-power per year — that it will be a burden on the people who derive a benefit from its development. Those people who do not receive the benefit, say, of electric power or electric lights, will not be taxed for it.

Without question, eventually it will be best to bring municipal plants under the operation of this section.

Section 15: The provisions of this section were a compromise.

The state of Maine jealously guards the granting of charters for developing its great ponds especially, and with a new and radical measure of this sort it was thought best not to insist that the Commission be given the power to grant such charters as the first draft of the section contemplated. It will be a long step in advance if persons or corporations desiring to create storage on a great pond be compelled first to apply to the Commission, who may then make an engineering investigation of same and report to the next legislature. It is probable that nearly all important measures that pass state legislatures or even the United States Congress are compromises to a certain extent. In the case of a meritorious measure it is generally possible to eventually improve it by subsequent legislation.

STATE SUPERVISION OF DESIGN, CONSTRUCTION, AND OPERATION OF DAMS AND RESERVOIRS.

BY FRANK P. MC KIBBEN, PROFESSOR OF CIVIL ENGINEERING, LEHIGH UNIVERSITY, SOUTH BETHLEHEM, PA.

[*Read September 18, 1912.*]

The Relation between the State and Engineering Construction is Unsatisfactory.

That many engineers are dissatisfied with conditions existing in the several states as regards the relation of these states to engineering construction which affects the body politic is shown by numerous discussions of state supervision of engineering works during the past year. These discussions were precipitated by the disaster at Austin, Pa., in September, 1911, when the failure of an unsafe dam revealed the astonishing condition that in the great Commonwealth of Pennsylvania a structure which endangers the lives and property of many people can be built in certain locations by any person whatsoever, and used without the least semblance of supervision on the part of the Commonwealth or any other competent authority. It makes no difference whether the builder be entirely ignorant of dam construction or not; he is perfectly free to erect a dam in those streams which have not been declared public highways by the legislature. Of course in such a case the public endangered has certain legal means of protection if it is made aware of its predicament, but such machinery is too complicated and inefficient to be worthy of consideration in connection with proper protective measures.

The engineering profession must have some form of supervision of structures possessing inherent danger, not only to secure better protection to life and property, in itself sufficient reason, but to prevent the erection of such structures by incapable persons, who, posing as engineers, thus reflect on the engineering profession as a whole. The Engineers' Club of Philadelphia recognized the need

of more efficient methods than those existing for securing engineering works of greater safety when it passed the following resolution on December 9, 1911:

"Whereas, the failure of the Bayless Pulp & Paper Company's dam on Freeman's Creek above Austin, Pa., on September 30, 1911, calls attention to the importance of insuring the safety of such structures where failure is a serious menace to human life; and, whereas, such structures should be entrusted only to engineers of ability and experience, who should have constant supervision of every phase of the construction; therefore, resolved, that the governor of the state is requested to call together a special commission of competent engineers, aided by legal talent, to frame comprehensive regulations providing for the creation of a permanent State Department of Public Works, to be composed of bureaus so constituted that their combined jurisdictions shall cover not only the construction of dams, but all other engineering contingencies likely to arise in the near future."

The Engineers' Club of St. Louis realized that a better system is necessary when, on February 18, 1910, action was taken favoring and urging

"the passage of such laws by Congress as will provide for a department or bureau of public works which shall include the Coast and Geodetic Survey, the Geological Survey and the Reclamation Service, River and Harbor Improvements, and such other branches of other departments as may be rationally coordinated under the one general department or bureau of engineering and construction."

The same dissatisfaction is apparent in Mr. Alfred Brooks Fry's letter to Governor Dix of New York when, on December 11, 1911, he proposed a State Department of Public Works consisting of a commission of five members with the necessary chief engineer and assistants to carry on all state public work including the state public buildings, the construction, operation, and maintenance of state canals and waterways, to perform the duties of the present Highway Commission, State Conservation Commission, Superintendent of Public Works, State Engineer, and State Architect, etc.

All these citations indicate a desire for more careful supervision

of engineering construction, and limitation of the right to build hazardous structures. Events of the past year clearly indicate the existence of this desire, but it is quite certain that if the engineers of the several states accomplish anything it is essential that united action of all engineering societies within those states must be brought to bear on their respective legislatures and that society resolutions and requests must be accompanied by personal solicitations on the part of individual members. The mere passing of resolutions will not be sufficient. And so it is with national legislation. Only by concerted action of many engineering societies, and by repetitions of their demands can anything be accomplished. If better state supervision of dams be desirable in Massachusetts, for example, the combined action of the Boston Society of Civil Engineers, the New England Water Works Association, and the engineering schools is required. These organizations must first reach an agreement as to what is best before they can go before a legislative committee to advocate improvements. Furthermore, it is only through national organizations acting in conjunction with local societies that anything like uniformity can be secured in various states. For example, if the two New England bodies just mentioned were to agree with the American Society of Civil Engineers on some form of state supervision of engineering works, and if similar action were taken between the national society and other state or local organizations, a great deal could be done towards securing uniformity in the different states.

In Pennsylvania there are four leading engineering societies, — the Engineers' Club of Philadelphia, the Engineers' Society of Pennsylvania, the Engineers' Society of Western Pennsylvania, the Engineers' Club of Northeastern Pennsylvania. These organizations, reinforced by the American Society of Civil Engineers, can and should take such action as will strengthen the status of public engineering procedure in the Keystone State. A joint committee representing the four state societies should decide on what legislative action is desirable relating to the formation of a State Department of Public Works which shall have supervision over all engineering matters coming under state jurisdiction. Armed with a proposal ratified by the engineering societies of the Com-

monwealth, the committee could appear before the legislature with such force as to command respect, but if each organization individually requests a different procedure it is perfectly evident that no action of importance can be secured.

What are the Conditions as to State Supervision of Dams and Reservoirs?

There are three main divisions into which a study of this question may be divided: first, the safety of the structures; second, the use of water for power, irrigation, ice harvesting, or recreation; third, the use of water for public water supplies. It is only with the safety of dams and reservoirs that the present paper deals, although the two other divisions are none the less important.

The following twenty-seven states have laws intended to provide supervision of dams and reservoirs: Colorado, Connecticut, Florida, Georgia, Idaho, Indiana, Kansas, Maine, Massachusetts, Michigan, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Wyoming.

These laws vary in value from the rigid Colorado law, which invests the state engineer and district water commissioners with great powers, to the obviously cumbersome inefficient method of local control by county courts or county commissioners. Fifteen states provide for state supervision, and twelve place local officials in control. Of those states having state officials or boards nine are west of the Mississippi River, and it is generally true that the laws of these western states are more rigid, more carefully and explicitly framed than those of eastern states. This is probably due to the fact that most of those in the western group are semi-arid, where regulation of water collection and use necessarily receive greater attention than in the East, where, because water is more plentiful, the subject has not received much consideration.

The laws of Oklahoma and Colorado are among the most stringent. They require preliminary approval of plans and specifications of dams and reservoirs by a state engineer, provide for his supervision during construction, and require a certificate of operation from the state engineer before the reservoir may be

used. The Colorado law contains articles covering the following points: State engineer must pass on all plans and specifications of reservoirs of capacity more than 75 000 000 cu. ft. of water, or having a dam or embankment in excess of 10 ft. in vertical height, and covering an area of more than 20 acres; he acts as consulting engineer during construction; has authority to require satisfactory materials and work of construction; must give owners a written certificate of acceptance upon completion of work; must annually determine amounts of water which it is safe to impound in the several reservoirs of the state. It is unlawful for owners to store water in excess of amounts specified, and water commissioners must withdraw excess waters if any exist; upon complaint of three or more persons residing or having property in such places as would be endangered by breaking of a dam or embankment the state engineer must examine the structure and if he finds it unsafe he must immediately cause water to be lowered to a safe level; appeal from decision of the state engineer may be made to county or district court, but judgment of the state engineer shall control until final settlement. Each county surveyor must inspect annually the reservoirs within his county and report his findings to the county commissioners, and if the owner or tenant of an unsafe reservoir or dam, after due notice, refuses to remove the danger, the county surveyor must lower the water to safety. The act states that its provisions shall not be construed as relieving owners from payment of damages caused by breaking or overflowing of dams or embankments, and makes owners liable. Owners of reservoirs pay actual expenses of state engineer in making personal inspection and also a per-diem rate and expenses of any deputy; and persons making complaints about the safety of any structure as above stated must pay the state engineer's mileage to and from the reservoir in question. The state engineer may use force to carry out the provisions of the act if necessary, and a fine is fixed in case any reservoir company fails or refuses to comply with his notice.

If judiciously and conscientiously enforced, the Colorado law should give good results; but it would be better to designate to the state engineer those duties and powers now assigned to the water commissioners and county surveyors. Furthermore, the

state and not individuals should pay expenses incident to examinations; and provision should be made concerning the reservoir owner's resident engineer.

Laws of the eastern states are generally inadequate. In Pennsylvania the State Board of Health passes on plans for reservoirs and appurtenances used for public water supplies, and the State Water Supply Commission by act of 1907 is invested with power of passing upon plans and specifications of dams to be built in those streams which have been declared public highways by the legislature. The Water Supply Commission has no power to supervise dams or reservoir embankments during construction, neither is it required to issue a permit for operation, nor has it the power to examine any existing dams, and has no jurisdiction over dams built before 1907. The concrete dam in Freeman's Run, at Austin, Pa., was finished in 1909, that is, subsequent to granting the power of approval to the Water Supply Commission; but the dam was not under the jurisdiction of that or any other commission, because the stream wherein it was located had not been declared a public highway. The failure of the dam just mentioned so aroused public opinion that the Water Supply Commission has made investigations of several dams suspected of being unsafe and it is also inspecting dams now under construction. It is quite evident that Pennsylvania has not sufficient protection against unsafe dams, but when the next legislature meets there should be no difficulty in securing additional enactments.

Whether this supervision will come in the form of enlargements of the State Water Supply Commission's powers or whether there will be a consolidation of several existing commissions into a State Department of Public Works remains to be seen, and the resulting action will be influenced by engineers only in so far as they act jointly through the various engineering societies of the Commonwealth.

The Water Supply Commission has done and is doing excellent work, and is amply able to carry out the statutes necessary to protect the state against repetition of Johnstown and Austin disasters. On the other hand, there are some strong arguments for combining several existing state commissions into a public service commission or into a department of public works. The

inadequacy of present laws for safeguarding against dam and reservoir failures is duplicated in lack of provision for oversight of bridges carrying railroad trains and street railway cars, and the legislature should give consideration to these and all such questions at its next session. Whatever form of administration the needed improvements may take they should be so simple that a suspected dam would be examined without appreciable delay by a competent state engineer, and if the structure were found to be unsafe the commission should have authority to act speedily and effectively.

In the West all work executed under the Carey Act, a congressional act permitting private capital to irrigate and reclaim arid lands, is under supervision of state boards or state engineers who are given the power of approval of designs, and who are to see that the dams, reservoirs, and ditches are properly constructed and finished in accordance with the original plans. But as each state where the Carey Act applies has passed its own laws regulating the control of work within its borders, there are, in consequence, considerable variations in the operations of this act.

State supervision is not always sufficient, and federal control might be necessary. For example, when a dam is constructed in a river forming the boundary between two states, it would be under the jurisdiction of the United States War Department only when the stream is navigable. In other cases, if each adjacent state had regulations which were actively enforced, it might be very difficult or impossible to secure concerted action on the part of the two states; at any rate, there would be a chance for conflicting authority, and federal supervision may be desirable. Another case which might arise is that of an unsafe dam in one state put near the boundary, and so situated that in case of failure destruction of life or property would result in an adjoining state. Of course, if each state had adequate supervision little chance would exist of this contingency arising, but if the state containing the dam had no efficient means of insuring safety, an effective state board in the endangered state would not have authority to act, and recourse would have to be made to public opinion or to the courts.

An Outline for Procedure is Recommended.

Assuming that state supervision to secure safety of dams, embankments, and reservoirs is desirable, how can it be exercised? The following outline is suggested:

1. Examination of plans and specifications by a properly organized state board whose approval is necessary before construction is begun. This approval should carry the proviso that a competent resident engineer be employed by the owner continuously at the dam under construction.

2. Examination of the dam or embankment during construction by competent engineers in the employ of the board. Inasmuch as the majority of masonry dam failures have been caused by faulty foundations, it is quite evident that inspection of the foundation as well as the superstructure is necessary, and that the board acting through its chief engineer must have the authority to secure changes in plans and methods if geologic or other features of the site require such changes. To make state supervision complete and efficient, a capable state engineer must see the work at important stages. Changes in original plans and specifications should be permitted only when allowed in writing by the chief engineer, and after a dam is finished no alterations should be allowed except with the written consent of the board.

3. Upon completion of the dam the state engineer should examine the structure and should require a report from the owner's engineer that the dam was built in accordance with approved plans and specifications and that the structure is a safe structure for the purpose for which it is intended. If the structure and report be approved, the board should then issue a certificate of operation.

4. Biennially after the dam is completed the owners should be required to have a competent engineer examine the dam and reservoir and to submit his report, together with any recommendation, to the board. It is the purpose of these biennial examinations to reveal any changes in and about the dam or reservoir which might endanger the safety of the structure.

5. At intervals not greater than five years, and oftener if necessary, the state engineer should examine each structure, and his reports should be published in the annual report of the board.

In case any repairs are shown to be necessary, either by the owner's engineer or by the state engineer, the board should order the owner to make them or to lower the water, and if he refuses, the board should apply to the judge of the county court for enforcement. Furthermore, at any time upon petition of three or more residents or property owners who consider their lives or property in danger because of the presence of a suspected faulty dam, the state engineer should examine the structure, and if repairs are necessary the board should proceed as above. Nothing in the act should relieve the owner of his full responsibility for the safety of the structure.

State Supervision is Desirable but is Not a Panacea.

Many people believe it desirable to establish state control over such works as dams, reservoirs, and bridges because failures of these structures endanger life and property. Probably a very much smaller number of people hold the view that the state should exercise no control whatever over these works of engineering when owned by private interests. State ownership or control does not prevent all accidents. Nevertheless, the state, that is, the people acting through certain officials, should exercise some control over structures which involve potential danger from the fact that they confine great forces of nature which if not restrained would cause loss of life or property which because of their magnitude and peculiar nature have inherent danger. As population becomes more dense, state restrictions are the more necessary. It seems therefore that state supervision is justifiable and, if properly administered, is an additional safeguard to life and property, and if of such a nature as to be an additional factor of safety or to reduce the possibility of disaster, while not relieving the owner of his responsibility, it is certainly a very desirable thing to have.

No one familiar with the action of state departments or government control or government ownership believes that these are infallible agencies of preventing disaster, but the safe and sane position to take is that they simply serve as additional means of seeing that the engineer's ideas as embodied in his plans and structures are correct. The objection has been raised against

state supervision that in case a structure were approved by a state board it might relieve the owner of damages if the structure later by failing caused loss of life or property. It is not a question of who is to be liable in case a structure falls down. It is a question of preventing its falling. Furthermore, with no supervision whatever in the case of Johnstown flood, no remuneration was forthcoming from the owners, and it is apparently true that those who suffered losses at Austin, Pa., will receive no payments for those losses. In both these cases the full responsibility rested on the owners, the state sharing none.

DISCUSSION.

Mr. John C. Trautwine, Jr. Mr. President, I have a special interest in Professor McKibben's paper; first, because I hail from that unhappy state whose plight he has so graphically described; a plight, which, however, judging from the papers we have heard read this morning, is shared by other states, notably by Connecticut, New York, and Maine.

Another reason for my special interest in Professor McKibben's paper is that I was the author of the resolution (though not of the preamble) adopted by the Engineers' Club of Philadelphia and quoted by Professor McKibben.

Professor McKibben remarks that the three utterances, that by the Engineers' Club of Philadelphia, that by the Engineers' Club of St. Louis, and that by Mr. Fry, all seem to aim at improvement in the safeguarding of dams. While this is true, the significant fact is that each of those three utterances aims at the substitution of order for chaos, — at the simplification and unification of the governmental process by which dams shall be safeguarded. It was just there that I, as the obstinate juryman, felt constrained to take issue with my colleagues on this committee of three appointed by the Engineers' Club of Philadelphia to consider the whole question of the inspection of dams. The result was my minority report, quoted below, and concluding with the resolution adopted by the club.

Our conferences, in committee, had not proceeded far before I discovered that it was impracticable for us, in the limited time

allotted, to specify confidently, and in detail, what the state ought or ought not to do in the premises: and then the thought dawned upon me that, in seeking to draw up, at short notice, a program for the state to follow, in regard to dams alone, we were going about the matter in the wrong way; that, in the state administration of public works, we had a sort of crazy patchwork, and that what was first of all needed was unification in the state's engineering operations, as a whole, including not only the matter of dams, but all other technical matters, and that this work could not properly be performed in a few days by a club committee. I therefore submitted the following minority report, which I venture to submit as a contribution to this discussion.

1. In sparsely populated and agricultural countries, the individual needs but little protection from the state; but, as population becomes dense, as great corporations arise, and as structures are erected whose failure means great loss of life and property, the state is forced to assert itself more and more actively, and in new directions, for the protection of its citizens. At a country crossroads, traffic may be left to regulate itself. On Broadway, freedom of action requires that the will of the individual be subordinated to the autocratic control of the policeman.

2. We long ago recognized the necessity and propriety of governmental inspection of buildings, of boilers, and of elevators; we have more lately sanctioned inspection of foods, governmental regulation of railways, etc.; and now the failure of the dam at Austin, Pa., and the later failure of that at Macdonaldton, Pa., have reminded us sharply of the necessity for similar control over dams.

3. It might be argued that self-interest should lead builders of engineering structures to take sufficient precautions; but such disasters as the two mentioned and the collapse of the Quebec bridge show that we cannot safely rely upon self-interest of builders to work in that direction, or leave the design and construction of such works to their uncontrolled decision, and that the state, which can earn no profit by cheapening the structure, should have the final control.

4. State or national control of dams is therefore a public necessity and in line with the inevitable trend of society.

5. State control might be exercised by a state engineer of dams, by a standing or special board of commissioners for dams, by some existing branch of the state government, such as the Water Supply Commission, or by a State Civil Service Commission,

before whom all engineers should be required to qualify before being permitted to construct important dams.

6. (This is the significant preamble, containing the sentiment expressed by the St. Louis Club and by Mr. Fry.) But it is unworthy of the dignity of a great state that such matters are taken up in haphazard fashion, awaiting disaster in some particular class of structures, and then awakening to the necessity of providing against that particular form of catastrophe. Such a policy leads to the creation of a heterogeneous collection of imperfectly correlated governmental bodies, clothed with conflicting or overlapping powers and of very limited combined efficiency.

And it was for that reason that I urged the following, which was adopted as the sense of the club:

7. The governor of the state should therefore be requested to call together a special commission of competent engineers, from this or from other states, or both, aided by legal talent, to frame comprehensive regulations providing for the creation of a permanent State Department of Public Works, to be composed of bureaus so constituted that their combined jurisdictions should cover not only the construction of dams but all other engineering contingencies likely to arise in the near future.

Mr. M. O. Leighton.* Mr. President, governmental control is a somewhat peculiar and diverse subject concerning which there are many different opinions.

I believe it to be true that, if a man desires to be completely independent, he must live alone. His independence will always be compromised if he lives in the same locality with another person, and it will progressively decrease as the population increases, until in a large community that man finds himself hedged about with so many limitations upon his complete independence that it sometimes appears as though his whole life were governed by precepts and ordinances enforced in the interest of the other fellow. So by progressive stages throughout the entire history of the development of civilization it has been inevitable that individual interests must give way to common interests when the former are antagonistic to the latter. I believe that this is a crude expression of the principles governing community life. The facts constitute a justification for the governmental control

*Chief Hydrographer, United States Geological Survey.

of public utilities or the control of all matters in which many persons have a common interest. The safety, happiness, convenience, and progress of the people must be conserved by uniform regulations enforced by the people's representatives.

The facts given in the papers on the subject of control of dams demonstrate clearly the necessity for some control, and I personally believe that that control should be by the state when the matters are exclusively intra-state, and of necessity by the Federal Government when those matters involve interstate relations.

It is a curious fact that the construction of dams, upon the integrity of which the comfort and safety of so many people depend, is subject to little or no governmental control. Contrast this with the fact that if a man desires to build even a one-story structure in the city, he must usually build it according to certain regulations and limitations. If he wishes to hang a sign over the sidewalk the work must be done in a prescribed way because of the danger which might arise to the public in case that work were not done in a proper way. In many states and communities sanitary authorities control the construction of plumbing in buildings notwithstanding the fact that it has been demonstrated that bad plumbing has a remote if any connection with disease. I may go further and cite the fact that a man cannot operate a peanut push-cart in our large cities without securing a license and doing the work under certain regulations. In view of the fact that so many of these relatively unimportant matters are subject to governmental regulation, is it not strange that a man can erect almost any sort of dam that he chooses in nearly every state in the Union without adequate regulation? There are laws, of course, in many of the states, the names of which are given in Professor McKibben's paper, but notwithstanding these laws, there are examples of bad dam construction in nearly all of the states, which construction was performed openly. Of course, there is always redress in such cases on the part of the public, but the procedure is usually indirect and inconvenient, and it is very true that that which is every one's business usually turns out to be no one's business. Bad dams are erected in spite of the law and in the sight of the people.

The condition that I have described not only results in danger to

human life but it greatly impedes progress in water conservation. Every one will agree that when a country becomes more and more thickly inhabited, it becomes correspondingly necessary to conserve water in reservoirs. That means the construction of dams It happens that in connection with some of my official work during the past few years I have advocated certain large reservoir installations. The idea has been fiercely combated by many good men, and it is noticeable that these men as a rule finally resort to a gruesome picture of the consequences of dam failure. It is a striking argument in the public mind. It is easier to discredit dam construction by doleful references to the few dams which failed than it is to support the idea by comforting references to the hundreds which have not failed. Of course we are bound to progress in the right direction irrespective of any specious arguments, but progress in the reservoir direction will always be impeded so long as the opponents find opportunity to cry "Wolf." It is necessary, therefore, to construct good dams in order to avoid the failures and to establish in the public mind the confidence in dam structures which under good engineering practice they fully deserve.

Among the states mentioned by Professor McKibben, there is one in which the regulations are supposed to be very good. In spite of them, however, an earthen dam was erected in that state not long ago which by reason of a fortunate train of circumstances came under the observation of two competent engineers before the outlet gates had been closed. One of the striking results of this examination was an experiment which they made to determine whether the dam would hold water. They excavated a hole in the ground at the upper toe of the dam, and found to their surprise that they could not bring water to that hole fast enough to fill it. It all seeped out under the dam. Of course, had the gates been closed, and had hydraulic pressure been put upon that dam, it would have failed and would subsequently have been cited as another example of the failure of *good* dam construction.

The procedure recommended by Professor McKibben for governmental control ought to serve admirably, but he is eternally right when he speaks of the lack of infallibility on the part of

government officials who are supposed to guarantee the stability of dams. However faithfully a state engineer or an engineering commission may be, mistakes will be made. We have not reached the point of infallibility. Therefore the public at large must bear its share in the responsibility and take an interest in these matters even though they have apparently provided for safety through the enactment of suitable statutes and the appointment of suitable boards of control. As in many other features of public improvement, public instruction is necessary and all standards must be raised, the standards of the public as well as the standards of engineers. In the education of the public the procedure recited and recommended in Professor McKibben's paper will be effectual.

Dam construction involves three factors of personal control, — the owner or projector, the engineer, and the contractor. The owner will be suitably educated by the enforcement of the laws which regulate the construction of dams, if they are as good laws as they ought to be. The engineer must also be educated; he must qualify. You are familiar with the agitation concerning the licensing of engineers. I am not going into a discussion of that, but will state simply that I have yet failed to find any real reason for opposing such a project. We require a physician or a lawyer or a marine engineer or a pilot to demonstrate whether or not they can satisfactorily perform their duties before they are allowed to enter upon them. Why should this practice not prevail with reference to the civil engineer? Consider any of the dams that have been erected, especially in the eastern part of this country. What physician has so large a practice that there are dependent upon his wisdom in any one day, or in any one year, the lives of so many persons as are dependent upon the wisdom of an engineer when he builds a dam above a populated valley? Why should an engineer be allowed to build a dam if he is not qualified, and by *qualified* I mean qualified to build a dam. Engineers should be classified. The fact that a man is able to lay street pavements or to build a sewer system is no guaranty that he would be a satisfactory person to construct a dam. There is no particular difficulty in the classification of engineers according to their abilities. Such a procedure is already in effect in many lines of

work. Take, for example, the marine pilot. If you will examine the license of a pilot in charge of a boat on the Potomac River you will find that license limits him to certain regions. He is confined to the Potomac River and possibly Chesapeake Bay, but he is not authorized to take charge of a steamer in New York Harbor or in Puget Sound. This classification of engineers would be quite as easy if the legislative procedure were properly outlined, and an engineer who undertakes a piece of work that may be hazardous to public safety may well be examined and qualified along those lines.

Consider the contractor. It is undoubtedly true that many dam failures have been caused by poor work on his part. You know the predicament of a contractor who is losing money on his job, and how easy it is to consider the fact that the poor devil *is* losing money and therefore to allow a little indulgence here and there. To secure a good piece of work under such conditions, eternal vigilance is usually necessary, and few of us measure up to eternal vigilance. One of the best ways to obviate such a difficulty is to abolish that absurd and antiquated regulation which prevails, especially in public work, that the contract shall be awarded to the lowest bidder regardless of the cost and the difficulties and regardless of the real responsibility of the man. In ninety per cent. of the cases, and probably more, the expense, trouble, and delay caused by a defaulting contractor who is awarded a job at too low a price, more than exceeds the difference between the successful bid and the rational one.

Mr. Edmund M. Blake.* The excellent papers of Mr. Chandler, Mr. Babb, and Professor McKibben, on the general subject of state control of the design and construction of dams, have been read with much interest, especially the reference in the latter paper to the methods of handling this important subject in the states west of the Mississippi River.

In the great arid region of the United States, on both sides of the Rocky Mountains, the annual precipitation is extremely low, and a very high value is consequently placed upon every gallon and every second-foot of water. As a natural result of this condition, the laws in general which have been passed by the legislatures of

*Assistant Engineer, Massachusetts State Board of Health.

the arid states have been much more strict with reference to the means employed to conserve water than the few similar laws which have been passed in the eastern states. In most instances, as cited by Professor McKibben, the arid states have adopted effective and stringent laws bearing upon the design and construction of dams and reservoirs for the storage of water, with the provision for wide power to be exercised by state departments and state officials in these matters.

The Government Reclamation Act, under which national funds are spent in the construction of dams, reservoirs, pumping plants, and canal systems for the irrigation of public lands, carries with it government control of the design and construction of all of the works. The splendid structures erected under the government engineers are a lasting monument to the excellence of their design and construction work, although money has not been spared where its use would increase the safety, permanency, and stability of the massive dams which store the water of the mountain streams for use in the arid plains below.

Paralleling the Government Reclamation Act is the very brief but far-reaching Carey Act, which makes it possible for private capital to engage in the reclamation of arid public lands, and the total acreage covered by work under the Carey Act is much larger than that covered by the Government Reclamation work up to the present time. The Carey Act gives the arid states the right to request the segregation by the government of areas of the public domain not already set aside by the Reclamation Service, and empowers the different states to control the works of reclamation by private capital of the lands so segregated. As Professor McKibben cites, each of the states in which work has been done under the Carey Act has passed its own special laws and regulations for the control of irrigation works. The writer is quite familiar with such laws as passed in Montana, Wyoming, Utah, Idaho, and Oregon, all of which differ materially from each other, but all of which, in the main, place in the hands of the state engineer the approval of plans and specifications for the construction of the works and direct him to make such inspections of the same as he may deem necessary or desirable.

In the state of Idaho, which has more than doubled in popula-

tion during the last decade as the direct result of irrigation, the state law provides:

First, that the sufficiency of and title to the water rights for a proposed Carey Act project shall be approved by the state engineer;

Second, that the segregation of the lands requested shall be approved in final form by the government and the State Land Board; and

Third, that the irrigation company proposing to reclaim the lands shall enter into a definite contract with the state, approved by the Attorney-General, which contract must embody the plans and specifications for the construction of the proposed works in form passed upon and approved by the state engineer.

In the contracts of this kind with which the writer has been intimately familiar, the principal requirement of the specifications is that the combined natural flow of the source of supply and the amount in storage shall be amply adequate to furnish water at the point of delivery to the settler at the rate stipulated in the contract, which, in general, is one eighth of a second-foot per acre, continuous flow, and that the entire canal system shall have adequate carrying capacity.

As a general rule, the great desire of Carey Act companies to hold the opening public sale of their lands as soon as possible, for financial reasons, leads them to rush through the preliminaries of engineering investigation and detail design, with the result that the plans submitted for dams are usually of a very general nature and seldom anything like the plans under which the dams are finally constructed. It is, therefore, plainly seen how important becomes the power given to the state engineer in the matter of the approval of final plans for construction and the inspection of the work during all stages of its progress. Too often inadequate inspection is given to the nature of the geologic formation under the massive storage dams constructed on these private projects. Below most of these dams are located the newly organized towns which are to become centers of the industrial life of the new tract and to which the safety of the dams above them is absolutely essential.

As provision is made in the contracts with the state for trans-

ferring to the settlers under a Carey Act project all of the structures and works for irrigation, after the payment by the settlers of a certain percentage of their water rights, two things at once become evident; first, the patent desire of the private corporation to expend as little money as necessary to meet the final approval of the state; and, second, the importance to the settlers of being assured that what they are to eventually pay for, take over, operate, and maintain, shall be of a permanent and adequate nature. The accomplishment of this result, and hence the prosperity of the settlers on nearly 3 000 000 acres of land in Idaho alone, depends largely upon the supervision and control of the state engineer.

Right here comes the vital obstacle, in my mind, to the successful carrying out of even the most effective and stringent state laws for the control of the design and construction of engineering works, namely, the regrettable insufficiency of the money appropriated by the legislatures of the arid states for the use of the state engineer in the employment of skilled engineering services to properly inspect the construction of these dams at every stage from beginning to end. In general, the state engineers are men of experience and ability, but the position is an appointive one, liable to change at any election, and the duties imposed upon the state engineer are so varied and numerous, and call for his attention over so vast an area of land as is covered by most of the arid states, that it is absolutely out of the question for him to give effective personal attention to dams and reservoirs. His appropriation for assistants is generally limited, and the men employed, in general, are sadly lacking in the experience which such important works demand. The result has been that inspection during construction has been intermittent in most cases, and thereby inadequate and unsatisfactory. In the noted case of the Mackay Dam, on the Lost River Project, in Idaho, the inherent defects were not discovered until construction work was well advanced, at which time the entire project was held up and thousands of settlers were financially damaged. It was a noteworthy fact that, in this particular case, attention to the defects was made public by parties outside of the state officials and departments.

Similar instances might be quoted where lack of proper inspec-

tion by the state has resulted even more seriously, not yet in any notable failures of dams with resulting loss of life and property, but with reduced storage capacity and consequent loss to the settlers depending upon that storage at the critical stage of the irrigation season.

Familiarity with the conditions in these northwestern states has led me to the firm conviction that the remedy must come from a keener public sense of appreciation of the necessary and invaluable work of the engineer in safeguarding public interests by rigid inspection of the construction work on dams and reservoirs, with power to change plans and hold up construction work when necessary. This aroused public feeling would then result in the appropriation by state legislatures of adequate sums to attract and make it possible to employ skilled and adequate engineering service, without which the vast engineering works so vitally affecting the prosperity of the new communities of the Northwest will fail to accomplish the purposes for which they were originated. The fault lies not so much with the hard-working and generally able and honest state engineer as it does with the limitations which are placed upon him in the employment of skilled assistants through the failure of the general public to insist upon the appropriation of adequate sums by the men who represent them in the state legislature.

SOME FEATURES OF THE CONSTRUCTION AND FAILURE OF THE AUSTIN, PA., DAM.

BY T. CHALKLEY HATTON, C. E., WILMINGTON, DEL.

[*Read September 19, 1912.*]

The writer has deferred saying or writing anything about the failure of the Austin dam because of a pending suit against the owners, and his desire was to have this suit first settled.

It seems to be appropriate to here present some features of the construction and subsequent failure of the work as an argument in favor of Professor McKibben's proposition for state supervision of dams.

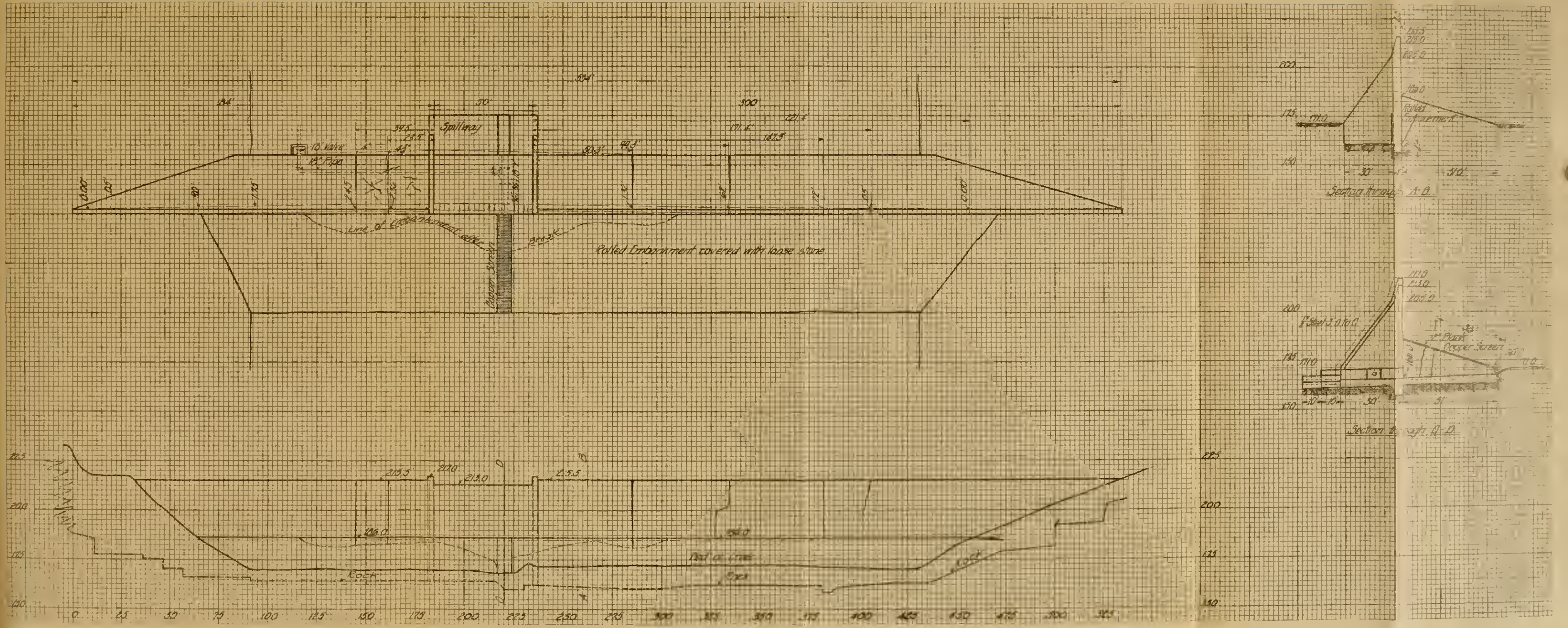
Several engineers who have publicly expressed their opinions of the cause of the failure of the Austin dam have made a very serious mistake in not differentiating between the failure of this dam and its demolition.

This dam failed January 23, 1910, and was demolished September 30, 1911, over eighteen months later. After January 23, 1910, the structure could not be termed a dam; it was a vertical wall broken in five or six distinct and separate sections. The same causes which effected the failure were only indirectly the cause of the demolition.

Having seen the dam very often during its construction, and during all of its stages; having been on the dam during its failure, and viewing its movement downstream, and having made as thorough an examination as possible the following day, after the water was emptied from behind it, I should be better qualified to determine the cause of its failure than those who have examined it after its complete demolition.

The Austin dam failed at the intake which was near the center of the spillway by dropping down at the toe some 6 in. and sliding out at the spillway about 18 in. The concrete did not slide on its sandstone base, but one stratum of the underlying sandstone slid

Plate VIII



Plan of Austin Dam made from measurements taken January 25, 1910, the day after its failure.

upon another after the intervening stratum of shale and gravel had been softened by the water seeping through this stratum.

This result was very apparent on the morning of January 25, 1910, after the water was out. The intake walls, which were built against the upstream face of the dam, and at right angles thereto, were pulled apart near their center in an almost vertical separation 18 in. wide. The underlying rock stratum upon which this wall was built had a vertical cleavage parallel with the face of the dam, about 12 ft. upstream from it, immediately under the vertical separation of the intake walls, and of the same width. No better evidence could be obtained as to what happened when this dam failed.

The center of the dam bowed downstream about 31 in. at the top, the bow running to zero about 110 or 115 ft. either way. There were four or five vertical cracks entirely through the dam in this 220 or 230 ft., and one vertical crack nearer the west end which did not extend the full depth of the wall. These cracks divided the dam into five or six distinct and separate sections.

As the dam slid down in the center, the earth immediately below and adjacent to it was pushed up quite perceptibly. This earth and the underlying sandstone strata, against which the downstream face of the dam was built, was the only thing which saved the dam from total demolition in 1910.

Plate VIII is a plan made from measurements taken January 25, 1910, the day after the failure.

Since January 25, 1910, water has been constantly impounded by this broken concrete wall. The depth of this water has varied from 25 to 52 ft. During this period water has continued to leak through the underlying strata, and this leakage, going on at great pressure, must certainly have washed much of the shale and gravel away, leaving the heavy concrete walls with less and less foundation until the final collapse came on September 30, 1911. It is therefore not hard to imagine that the condition of the foundation at this latter date was far different from what it was eighteen months earlier. When the water reached its maximum height on September 30, 1911, it was simply a matter of first a dropping of the wall and then a movement of the different sections, resulting in stresses which could not be computed, and which

would not have taken place if the wall had been a monolith, as it was on January 23, 1910.

So much for the difference between the failure and demolition of this dam; now I want to correct some false statements which have been publicly made by some of my professional brethren in their desire to determine logically the cause of the failure of the dam.

The conditions governing the design of the dam were not unusual. I had a client who placed upon me two limitations, minimum cost and maximum height. The first was \$85 000 and the latter was determined by securing an impounding area of 200 000 000 gal. of water.

In order to fulfill these two conditions, I made three separate designs, reducing each cross-section a little until I got the least which I believed to be safe. This section did not provide for any leakage under the dam, nor did I expect it.

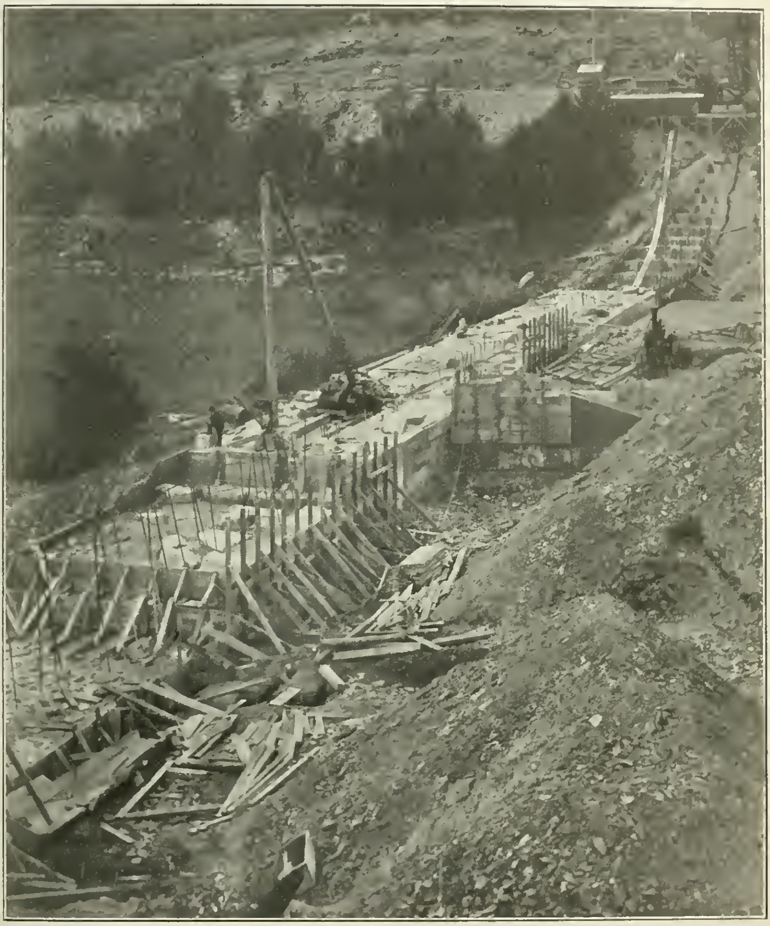
I knew the nature of the foundation, for I had sunk pits upon the site of the dam before designing it. I had also carefully examined the nature of the underlying rock, which could be clearly seen throughout the valley. I expected to prevent leakage under the dam by building a very stable upstream embankment against its face, which I also expected would reduce the hydrostatic pressure against the dam.

To increase the factor of safety against overturning, I placed steel rods in the upstream portion of the wall. These were 1¼-in. steel rods 25 ft. long, sunk 6 to 8 ft. in the underlying rock strata, and secured thereto by expansion bolts, the holes being filled with cement mortar.

To increase the factor of safety against sliding, a key or cut-off wall was built into the rock on the upstream face of the dam, forming a vertical projection of the dam. This wall was 4 ft. wide and from 2 to 4 ft. deep.

The weak part of the dam was at the intake, where there was no embankment against the upstream face, and where a hydrostatic pressure was exerted against the dam due to the full depth of water to its foundation, approximately 53 ft.

To overcome this extra pressure I built against the downstream face and over the full length of the spillway a heavy concrete wall 7 ft. deep. However, this is the point where the dam failed.



THIS VIEW SHOWS THE REINFORCEMENT, KEYWAYS AND LARGE STONES FORMING CONCRETE.

When this dam bowed downstream in 1910, there was a space left between the embankment and the face of the wall, leaving the embankment of no further use. I am quite sure, however, that this embankment did prevent leakage under that portion of the dam with which it was in contact, and, had the center of the dam held, the embankment would have fulfilled the purpose for which it was built. The next day after the failure I dug several holes in the surface of the embankment and found it dry 3 ft. deep, showing that very little penetration had resulted after two months' submergence. After the failure, this embankment still stood, and even after the demolition a large portion of this embankment is still standing. It was well built, with good material deposited in 6-in. layers and thoroughly rolled with grooved rollers.

The great mistake I made in building this dam was trusting to the rock foundation as being impervious. I am just as fully alive to this mistake as are several of my critics who seem to think a careful and experienced engineer could not have so erred in judgment; but I want to tell these critics a few things which influenced my judgment.

About 860 ft. above the site of the new dam another dam had been built some twelve or thirteen years before. This dam was 20 ft. high, and impounded about 26 000 000 gal. of water. It consisted of a rubble stone masonry core wall 12 in. thick on top, and stepped down to 4 ft. 6 in. on the bottom, which was built on the surface of the same sandstone stratum upon which the new dam was to be built. The dam had an embankment on the upstream face with a slope of 2 to 1. The embankment on the downstream face had been washed away, exposing about two thirds of the core wall.

The only place where this dam leaked was through an old clean-out pipe which had been abandoned, and which the owners had unsuccessfully tried to stop up. There was no leakage apparent in the valley below.

When building the new dam I had the foundation rock drilled with 2-in. drills from 10 to 15 ft. deep and from 15 to 20 ft. apart over the entire foundation. I did this for the purpose of testing the underlying strata. These holes were drilled under my personal supervision.

These holes were free of water at all times, except such as was poured into them by the driller to prevent the heating of the tool. These holes were drilled through the same strata of rock upon which the water back of the old dam was lying, and the bottom of the holes were from 60 to 65 ft. below the surface elevation of the water. If these strata had not been water-tight my conclusion was that any leakage from the old dam would have shown in these holes.

This seemed a logical conclusion then, and, upon explaining the condition to many well-informed engineers since, it has appeared to be logical to them.

The test holes sunk into the rock showed good solid strata of rock from 2 ft. to 4 ft. thick, with intervening strata of gravel and shale. These strata were so compact that they were almost as hard to drill through as the rock.

I want to correct some misstatements about how the dam was built. These misstatements have been made by those who did not witness its construction, but who have made an examination of the broken pieces of the dam since its demolition.

In preparing the foundation, care was taken to remove the thin strata of sandstone and shale until firm and thicker strata were exposed. The best evidence that this was actually done are the progress photographs, which distinctly show two things respecting this point. They show the foundation cleaned for concrete and the thickness of strata where the trench was cut out to build the cut-off wall. They also show great quantities of these top strata piled upon either side of the excavation. Most of these stones were removed to the crusher plant and broken up for concrete.

Every section of the foundation rock was carefully cleaned of all shale, gravel, or clay, and thoroughly washed and scrubbed down before any concrete was deposited upon it. Every large stone deposited in the concrete mass, to which any foreign substance adhered when it came from the quarry, was thoroughly cleaned and scrubbed. These large stones were carefully selected in the quarry after the blasts were made, and were stored in a separate place for the supervising engineer to inspect before they were lowered into the concrete.

There was a cut-off wall built throughout the entire length of

Fig. 1.
The Upstream Face of Dam. The Waste Stone in the Foreground came from the Foundation.

Fig. 2.
Showing the Character of the Rock in the Foundation.

the dam. This wall was 4 ft. wide and from 4 to 2 ft. in depth. I looked upon it more in the nature of a key wall than a cut-off wall. All of it was built under the protest of the owner, who could not be convinced of its necessity.

Steel rods $1\frac{1}{4}$ in. in diameter and 25 ft. long, spaced 2 ft. 8 in. on center, were built into the dam vertically. These rods extended down into the rock foundation from 6 to 8 ft. and were secured by expansion nuts and cement mortar. It has been claimed that these rods were left out in many places. The best evidence that they were not are the progress photographs, which clearly show them across the entire dam.

The concrete used in the heavier portion of the wall was what is known as "cyclopean." The large stones were embedded in various ways, some as headers and some as stretchers; some on their greatest beds, and some on edge. Every large stone was surrounded with from 4 in. to 12 in. of concrete, which was deposited very wet and well spaded in.

The concrete mass consisted of one volume of Pennsylvania Portland cement, three parts of crushed sandstone dust and fine screenings, and six parts of crushed sandstone, the size of the stone corresponding to the run of the crusher up to two and one-half inch stones, with dust, screenings, and one-half inch stone eliminated. All the cement used was tested upon the work, a testing plant being maintained there. A boiling, setting, and tensile test was made of every carload, and no cement was accepted which gave evidence of being unsound, of too rapid setting, or whose tensile strength was below 200 lb. for twenty-four hours or 400 lb. for seven days, neat, or fell below 120 lb. after seven days old when mixed with three parts of the crushed stone dust we were using in the work.

The concrete was deposited in sections of 25 to 45 ft. in length of dam, the area of the section being governed by the amount of the concrete which could be deposited as a continuous operation. As each section was completed, keyways from 10 in. to 12 in. wide and deep were left in both the vertical and horizontal faces. Instead of leaving these keyways in all the horizontal surfaces, there were a few such surfaces where two rows of large stones were embedded in the surfaces so as to allow from 12 in. to 18 in. of

their depths to project above the finished surface of the concrete. These formed a tie for the next section of concrete.

It has been stated that the concrete was not properly jointed and that keyways were not left. The best evidence of this is the progress photographs, in which the keyways and projecting stones are clearly shown.

Great stress has been laid upon the weakness of this dam by reason of the laitance in the joints. Of course I cannot positively state a condition which I did not personally see, but I can state as a fact, from personal observation, that I never saw fresh concrete deposited upon concrete which had been set up before the surface of the old concrete had been well watered and thoroughly swept down with wire street brooms. After which the entire surface was sprinkled with neat cement mortar upon which the very wet fresh concrete was deposited.

The supervising engineer had been employed by me for several years, and had supervised a great deal of concrete work. He knew my methods, and I had great confidence in him in having them carried out. I do not believe this confidence was misplaced in supervising this dam. If any laitance was found in the fractured joints of the demolished dam it was no doubt the neat cement which had been spread upon the surface of old concrete joints, and which had not combined with the fresh concrete. I have known such a result to happen under my own observation.

I have been building concrete for twenty-five years under all kinds of conditions. I have tested it in a laboratory maintained under my direction for several years, and I believe I know what good concrete is when I see it laid, and I think I can truthfully declare that I never had better concrete built for me than I had at the Austin dam.

Of course the sandstone rock, of which this concrete is composed, is not as strong a mass as granite or trap rock would be, but the mixture could not be better made. Every day's run was checked up by the engineer to see that the proper volume of cement was used, and we averaged, throughout the entire work, 1.25 barrels of cement to 1 cu. yd. of concrete. However, I believe an examination of the present pieces of concrete dam standing will show to any practical concrete expert familiar with the use

FIG. 1.
SHOWING THE VERTICAL KEYWAYS, AND LARGE STONES USED IN CONCRETE.

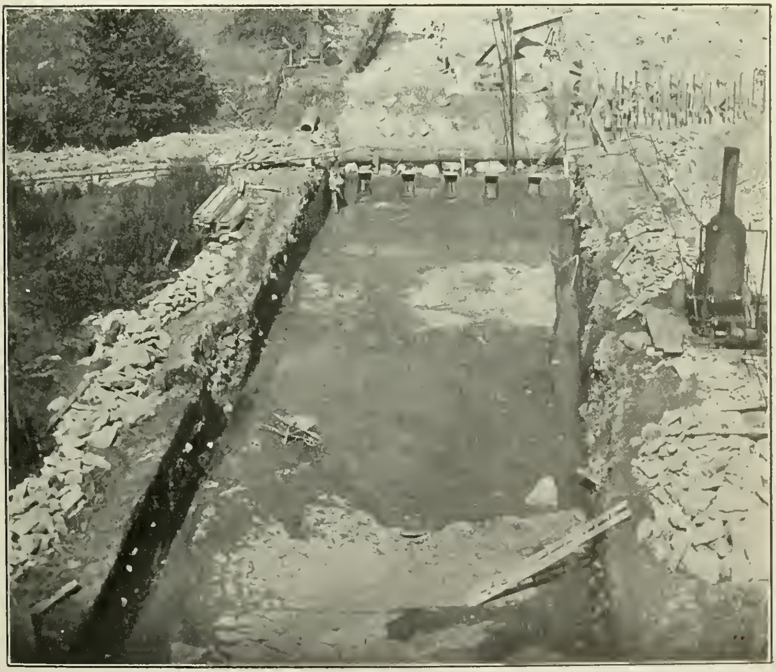


FIG. 2.
THIS VIEW SHOWS THE FOUNDATION UNDER THE SPILLWAY. THE TRENCH ON THE RIGHT HAS BEEN EXCAVATED FOR THE CUT-OFF WALL.

of this character of material, that the mixture in this dam was well made and laid.

In giving you the detailed description of the manner in which this dam was built, I am not trying to defend myself nor my supervising engineer, but to answer some of the unfair criticisms which have been made as to the quality of the work.

The failure of this dam was not the result of poor workmanship, but poor judgment upon my part in determining upon its foundation. I should have sought the advice of a man more skilled than I in determining foundations for dams. Had there been such a state officer it might have resulted in saving this dam and my reputation.

I was also too much influenced in my judgment by the necessity for keeping the expenditure within certain limits. I have since felt a very grave responsibility for my failure to advise my client early in my engagement that no paring down of this work should be countenanced. Had I done so, either the dam would not have been built, or it would have been built in accordance with my first design. The owner had no intention at any time of building a dam the safety of which he doubted, and no blame can be attached to him for its failure on January 23, 1910. He depended upon my judgment entirely, even though he may have tried to influence me to keep the expenditures down to the lowest possible limit.

To the young engineer who is called upon to design an important structure, the safety or sufficiency of which he is not entirely satisfied with, I would strongly urge the wisdom of calling to his help the advice of an older engineer especially skilled in that particular line. Never sacrifice safety for cost, no matter how urgent your client may become. He does not realize the danger, and you should. If you cannot agree with him, resign your engagement, for sooner or later the reckoning will come.

Now, just a word upon state supervision of dams. As previously stated in this paper, I think if a thoroughly competent state supervisor had been in office when this dam was designed it might never have failed, — but how are you going to get such a supervisor?

Since the failure of this dam, and its subsequent demolition, I have read every criticism from engineers which had come to my

notice. For the most part, these criticisms have appeared in the several engineering journals and society reports, and I have compiled a little book containing these clippings. As I have been deeply interested in learning all I could about this matter, I have perhaps thus accumulated more evidence of the difference of opinion as to how to build a dam, as expressed by engineers in good standing, than others who have not had the same incentive. In view of this information, I want to say that it would take a pretty good examining board to pass upon the qualifications for a competent state dam supervisor.

In the discussion as to the proper method of reinforcing this dam after its failure in 1910, I have five different plans from as many engineers, and each plan based upon totally different principles.

For evidence that the profession is not a unit upon just how to build a dam to make it safe, and still keep within the economic limits of cost, you need only refer to the numerous dam failures both in this and in foreign countries. Their number far surpassess the number of failures of any other character of engineering structures.

DISCUSSION.

Mr. John C. Trautwine, Jr. It was about a year ago that the demolition of the Austin dam occurred, and shortly after that it was very actively considered by engineers. But, since then, many things have happened to engross our attention, and I came here entirely unprepared to have the matter brought to my recollection. I therefore regretfully allowed the paper to go by default, immediately after its reading, but it appears to me unfortunate that such should be the case, where the author has made so commendable a statement of his case, exonerating his associates, where this was possible, and frankly acknowledging the extent to which he considers himself at fault.

For myself, I have also to make a confession, of which I was reminded when Mr. Hatton referred to those who, with insufficient qualification, had expressed views with regard to the disaster, my confession being that I ventured to express a view without having seen the dam, either before or after its failure; but the case was

very fully and clearly described and illustrated in our technical journals, and these accounts seemed to make it quite certain that the failure was due to the cause which Mr. Hatton has assigned, namely, not the sliding of the dam upon the upper rock stratum, but the sliding of the dam and the upper rock stratum as a whole upon a lubricated stratum below. That view, I must confess, I expressed, at the time; and I am glad to find it shared by Mr. Hatton.

STATE REGULATION OF PUBLIC UTILITIES.

BY MORRIS KNOWLES, C. E., PITTSBURGH, PA., AND BIRMINGHAM, ALA.

[*Read September 19, 1912.*]

In looking back through the proceedings of this Association, the writer finds that no paper has been previously presented upon the broad aspect of this important question. This may be due in part to the conservatism of the engineering profession with regard to the discussion of public questions. That conservatism, however, is passing, and President John A. Ockerson, of the American Society of Civil Engineers, outlined the new attitude of the profession in his address before the annual convention at Seattle, Wash., in June, 1912, in the following words:

"There seems also to be a disposition to avoid participation in the discussion of public questions, even when closely related to the work of the profession. When congressional committees call on the Society for advice with regard to pending legislation, involving questions relating to engineering, it would seem to be a proper function of the Society to render such aid as may be practicable.

"In fact, it might be well, under proper conditions, to go even further and use the influence the Society may have to mold public opinion along lines free from local or political bias, when our public works are the subject of discussion."

In the opinion of the writer, this counsel might even have been made somewhat broader. Such an organization as this can perform a real public service by discussing not only public works but public policies involving principles for the consideration of which engineers and works-managers are better equipped by training and habits of thought than almost any other class of citizens. In the political and social revolution which is now going on before our very eyes, many problems are involved, in the solution of which the scientific honesty, the accuracy of reasoning, the conception of economy and efficiency, possessed by trained technical men,

should be of the highest value. In speaking to the students of Manchester University, June 28, 1912, on the social and political changes of Great Britain, Lord Morley said:

"Before losing heart, let us be sure that our political arithmetic and algebra are right."

The language is significant as indicating the attitude of mind which he considered most valuable in the premises, and which is characteristic of men in the profession in which we are engaged.

Of all the problems involved in this present-day revolution, none is more clearly within the class that we have mentioned than that which we have as a subject to-day, "State Regulation of Public Utilities." Assuming prominence as it does at the time of the downfall of the political boss, the crumbling of the political machine, the growth of direct legislation, and the promise of return to truly representative government, it is but one of the many indications of the abandonment of the policy of *laissez faire* and competition, and of its replacement by a new public policy which places the liberty of the community before that of the individual, and recognizes that the natural resources, the tools of production, and the devices which man has invented for their economical utilization must be used, not for exploitation in the interest of any one or any group of individuals, but for rational and complete development, in such a way as to best conserve the welfare of this and future generations.

The growth of this new policy can be traced back through history to the edge of the Dark Ages. The Reformation and the Renaissance, often considered merely religious and intellectual movements, were in reality manifestations of the beginning of a world-wide demand for greater individual social and political liberty. The American and French revolutions, the general political disturbances throughout Europe about 1848, our own Civil War, and the Chinese Revolution, have been but local manifestations of the same universal demand. As a result, during the last century almost all governments in the civilized world have been made over to forms guaranteeing a greater measure of personal liberty.

The industrial development and the growth of city life that

this revolution made possible, however, have brought about a realization that unlimited individual freedom is not an ideal state of society. Competition and *laissez faire* were well enough for the conquest of the forest and the desert. But as population increases and as economies become increasingly necessary, the unavoidable results of competition are increased control of raw materials and distribution, mass production, and combination. Equally inevitable results of the *laissez-faire* policy are exploitation and violation of community liberty in the interest of personal freedom. The last fifty years have therefore seen a new movement, manifested by legislation against trusts and against rebating, the public-health movement, the conservation of natural resources, — more latterly by the agitation of the newer doctrines of improvement of industrial and living conditions, regulation of public utilities, the regulation of all monopolistic business, direct legislation, state-insurance and minimum-wage legislation; and culminating in the present unprecedented interest and activity all over the world in the improvement of social and political conditions, that bids fair to reorganize society on a basis of the policy of social justice, even if it involves a restriction of hard-won individual liberty.

The basis of state regulation of industry is the fundamental common-law principle limiting the institution of private property itself. No man may use his property in a way opposed to the good of the community in which he lives, and which protects him in his possession of such property. A second principle, also inherited from the earliest days, is that he who devotes his private property to a public use thereby clothes it with public interest, which justifies not only great rights, but also public regulation. How far these principles are applicable to industry and business is to-day a burning question. We have heard the head of one great industrial combination declare publicly that the state should fix prices.

In a statement before the Stanley Committee at Washington, June 8, 1911, Judge Gary said:

" It seems to me possible that if there was a federal license law which enabled a corporation to apply to the government or a department of the government for a license to engage in inter-

state commerce business, then there could be considered and decided, first, all questions relating to the organization of the corporation itself; . . . and if it should be determined to issue a license, then one could be issued which might be revocable by the government, depending upon the conduct and management of the corporation — even relating to the question of prices, as to whether they were extortionate or not . . . or whether in any respect the conduct of the corporation was inimical to the best interests of the people generally. . . . Constructive legislation in this country is needed if we are to retain our position in the ranks of competing nations who are trying to make progress, and who are making progress."

Interesting as it would be, we cannot go into that subject here; nor can we inquire in great detail what uses of private property are public uses, and what industries are clothed with public interest. In various periods of history many different occupations have been considered subject to this principle. In medieval days the baker, the miller, the innkeeper, the barber, the tailor, the victualer, and the smith were required to supply all patrons on equal and customary terms. When physicians and surgeons were rare, they had to serve reasonably whoever called upon them. Later, with the development of towns, the ferryman, the wharfinger, and the carrier were held subject to public regulation. In the early days of the Massachusetts Colony, monopolies were granted to the trade guilds by the General Court and held to be public callings. Still later, the widest application has been given to the term at various times. Common carriers, water, gas, and electric companies, power companies, telephone and telegraph companies, warehouses and grain elevators, bridges, canals, ferries, waterways, draymen and hackmen, and many other lines of business have been held to be public callings. If we should go to the decisions of the courts with regard to what are public purposes, properly subject to government ownership, we find that libraries, theaters, hospitals, ferries, cemeteries, skating-rinks, musical entertainments, exhibitions of fireworks, employment offices, etc., have been included. In fact, the only test appears to be what the public good requires; and we may in future expect to see any business whatever in particular circumstances become regarded as a public calling and subject to regulation.

Interesting as this subject is, however, it has no part in this discussion, for the term "public utilities" has come to have a special restricted meaning, with but slight variation in different localities. This generally accepted meaning may be said to be well defined in a section in the public utility law presented to the General Court of Massachusetts at its last session. Omitting some of the legal phraseology it declared the term "public utilities" to include every individual company or corporation furnishing for public use any of the following services:

"(*a*) The transportation or carriage of persons or property, or both, between points within this Commonwealth by railroads, railways, electric railroads, or steamships, including express service and car service carried on, upon, or rendered in connection with such railroads, railways, electric railroads, or steamships.

"(*b*) The operation of all conveniences, appliances, facilities, or equipment utilized in connection with, or appertaining to, such transportation or carriage of persons or property, or such express service or car service, by whomsoever owned or by whomsoever provided, whether the service be common carriage or merely in facilitation of common carriage.

"(*c*) The transmission of intelligence within this Commonwealth by electricity, by means of telephone lines or telegraph lines or any other method or system of communication, including the operation of all conveniences, appliances, instrumentalities, or equipment utilized in connection therewith or appertaining thereto.

"(*d*) The production, utilization, sale, or distribution of gas, electricity, water, or energy for light, heat, fuel, or power within this Commonwealth, including the operation of all plants, conveniences, appliances, instrumentalities, facilities, or equipment utilized in connection therewith or appertaining thereto."

Even in the most individualistic times these services have been considered subject to public regulation and required to perform any duties laid upon them by statute. In addition they have been held to certain common law duties with regard to service and non-discrimination; and their rates have been regulated on the ground that they have no right to take a return on the unearned increment of their franchise value by charging what the traffic will bear. These duties have been briefly defined as follows:

1. To perform all duties required by statute.

2. (*a*) To serve all who apply.
(*b*) To provide safe and adequate service.
(*c*) To charge just and reasonable rates.
(*d*) To make no discriminations either in rates or in service.

It should be noted that these duties are all affirmative, differing in this respect from the negative obligation not to injure others by the use of property for private ends.

This is not the place to discuss the relative merits of municipal ownership and public regulation. Indeed, such a discussion would be entirely irrelevant to our subject, for, whether utilities are publicly or privately owned or operated, the need of broad regulation by the state or sovereign power is the same, and the methods and principles are identical. The duties of public utilities in the two cases are precisely similar. If the principles developed by countless decisions of courts and commissions are sound and just; if every applicant has the right to be served; if property should be so used in such services as to provide safe and adequate service; if discriminations are unjust and contrary to public policy; if depreciation ought to be allowed for; if it is unjust for taxpayers to contribute to lighten the burden of consumers, or for consumers to pay in rates any portion of general government expense, which ought in justice to fall on taxpayers, — then the regulation of public services is just as much the right and duty of the state in the one case as in the other. In its governmental functions the municipality is but the agent of the state; in its purely business enterprises it bears to the state the same relation as any other business corporation. Whether municipally owned public utility service be considered as belonging to either category, or as comprising functions in both, the grounds for state regulation are equally strong. This is a matter which should particularly interest the New England Water Works Association, as by far the larger majority of water works in New England are municipally owned.

Massachusetts, the first state going in for systematic public-utility regulation, recognized this principle in part and gave its Gas and Electric Light Commission the same authority in some matters over municipal plants as over private ones. The authority

of the state boards of health of Massachusetts, New York, New Jersey, and other states, over quality of water, is without distinction regarding character of ownership. In England this stand has long been taken with regard to such features as accounting and reports. In at least one respect it has been carried further there than in any state in this country, for there, municipally owned and operated utilities pay a property tax into the general treasury, just as other property does. The basic theory of this appears to be that consumers ought not to be relieved of a portion of their burden at the expense of other taxpayers, by having exclusive tax-free use of property, which seems logical, if companies are to be similarly taxed, and just in the light of the general principles that have been heretofore explained. But it is inconsistent with the English policy of allowing some municipalities to make considerable profits, applicable to the reduction of the tax rate.

Wisconsin, leader in the modern development of public-utility regulation, makes no distinction whatever between publicly and privately owned plants, and requires the same standards in both cases, for quality, accounting, rates, financial management, reporting, depreciation accounts, etc.

Hon. John H. Roemer, chairman of the Railroad Commission of Wisconsin, said in an address before the Trans-Mississippi Commercial Congress at Kansas City in 1911, —

> "The distinctive feature of the law, however, in Wisconsin is that of placing all municipal plants under the supervisory powers of the Commission to the same extent as privately owned plants. The wisdom of this policy is no longer disputable, for no greater benefit has been bestowed upon the public by regulation of public utilities than that resulting from the operation of the law upon municipal public utilities."

This may be opposed by some of the ardent supporters of local self-government; but local self-government does not mean a right to local mis-government. The rights of the citizen are just as much transgressed by a municipality which fails to fulfill its public utility duties as by a private corporation. As a matter of fact, regulation is sometimes even more necessary with a municipally owned plant than a private one; because people will often

endure service and rates imposed upon them by their own town officers which would call forth vehement protest if a private company were involved.

Massachusetts was the pioneer in public utility regulation, and has always led the country in the regulation of municipal accounting and municipal finance, making the most minute regulations with regard to some details. Nevertheless, it is interesting to note that the public utility commission bill, presented to the General Court last winter (but not passed), held municipally operated plants subject only to the requirements of the sections on "Accidents," "Accounting," "Reports," "Appraisal," "Access and Inspection," and "Standards and Tests," and exempted them from orders by the Commission with regard to service, rates, or discriminations. The benefit to be derived from the law, which will doubtless be enacted in the future, will be greatly increased if this error is corrected.

Recognizing, then, the benefit of regulation in all cases, let us discuss briefly the methods and principles that are to be followed. Regulation by special legislation or by court decisions have been proposed as sufficient by some, but neither expedient can be supported. With regard to the former, Justice Timilin of the Wisconsin Supreme Court in deciding one of the few cases, perhaps the only case, that has been appealed from the decree of the Wisconsin Railroad Commission, said,

"It is argued that the power to fix rates is a legislative one and can never be anything else; . . . that the legislative power is by the Constitution vested in the Senate and Assembly, and cannot be set apart except as expressly provided for in the Constitution; but when we add to this that, because of the multitude of detail, the intricacy of the subject, the expert knowledge required, the numerous separate investigations of inter-related questions of fact which are necessary . . . a legislative body . . . would find it an actual rather than a legal impossibility to fix just and reasonable rates, it becomes apparent that this position tends to the conclusion that the state . . . was shorn of some of its usual and necessary power of sovereignty and became impotent to exercise the power of regulation. Regulation by direct action of the legislature has been tried and found impracticable and its attempt generally abandoned."

The same reasoning applies equally well to regulation by municipal ordinance. It would demonstrate the uselessness of this method of regulation, even if local prejudices, local politics, and high feeling did not commonly make impossible the unbiased, judicial attitude which is the *sine qua non* of reasonable regulation.

Equally unsatisfactory is regulation by court decision. All over the country such tribunals are already overburdened with work, and action would often be delayed beyond the time where it would be of value. Moreover, the work requires more than a judicial mind. Engineering, financial, and business judgment must be possessed from actual experience, or understood from long consideration of such matters, to a degree that is usually impossible for the judge. Finally, court decisions must necessarily be, in general, corrective rather than preventive, and hence such regulation is contrary to our present-day ideas of governmental efficiency.

To change two words in the message of President Taft, advocating the establishment of a commission to investigate industrial strife, —

"At the moment when discomforts and dangers incident to *utilities service* are actually felt by the public there is usually an outcry for the establishment of some tribunal for the immediate settlement of the particular dispute, but what is needed is some system, devised by deliberate study in advance, that will meet these constantly occurring and clearly foreseeable emergencies, — not a makeshift to tide over an existing crisis. Not in a rainstorm but in fair weather should the leaking roof be examined and repaired."

A priori consideration would therefore lead us to the conclusion that a permanent commission is the correct solution of the problem, and experience has justified this conclusion. Massachusetts, Wisconsin, New York, Vermont, New Jersey, New Hampshire, Kansas, Oregon, Ohio, Washington, Connecticut, California, Maryland, Oklahoma, and many other states have legislation placing some or all public utilities under the jurisdiction of one or more commissions. The national experience with the Interstate Commerce Commission has borne splendid testimony to this method of regulation.

Opinion is practically uniform in the desirability of commission regulation; but there is still discussion as to whether utilities should be supervised by municipal or state commissions. In the writer's opinion municipal regulation alone will never be satisfactory. For municipally owned utilities such regulation is out of the question. The community of interest in making a good showing and the lack of perspective may often defeat the purpose. In the case of privately owned companies, the pressure of local prejudice and feeling makes difficult the preservation of the judicial frame of mind and spirit of fairness which are indispensable. In the case of a few large cities, high-grade city commissions have been partially successful. But even in these cases cities cannot afford expert service as extensive or of as high grade as is available when they act together through a state commission; and such local commissions have not an equal opportunity to gain such varied experience or to accumulate so large an amount of data that may be applicable to future investigations and decisions. Moreover, the intercorporate relations of most public utilities make effective local regulation as impossible in many cases as would be the regulation of interstate commerce by a state railroad commission. It is believed, therefore, that a single state commission with ample powers and conspicuous responsibility will be most satisfactory. This does not mean that in the largest cities local commissions cannot be of great value in investigating local conditions in greater detail, and in collecting local information; but even if they do exist, a state commission is just as necessary to supplement them, and to secure in their work uniformity, equality, and efficiency.

An objection often urged against any state-wide measure of this kind is that it means the domination of the cities by country districts and the "farmer vote." In matters of fundamental progress, however, the interests of city and country are one and the same; and apparent opposition often terminates in mutual benefit. You will recall an example of this at the time when the Metropolitan Water District of Boston undertook to condemn additional drainage areas in Massachusetts. The protest of the country districts resulted in an act by the General Court of 1907, requiring that all cities and towns in the Metropolitan Water

District "shall, after December 31, 1907, equip with water meters all water services thereafter installed for them, and shall also annually equip with water meters five per cent. of the water services which were unmetered on December 31, 1907." The effect has been to reduce the waste, to prolong the life of the works then existing, and to postpone the expenditure of great sums for extensions.

A further criticism of the commission idea is that the machinery may readily come under the control of a few bad men. No system can take the place of good men in public life. But experience has shown that when large responsibility is conspicuously centered on a few men, with full publicity regarding their proceedings, such fears are usually groundless. The recent tendency toward the commission form of municipal government is based on the same principle.

To quote again from Justice Timilin, in deciding a case appealed from the Wisconsin Railroad Commission, —

> "Experience tends to show that public officers, as well as private citizens, are apt to rise in character and dignity to meet responsibility, but to shift a responsibility where opportunity of shifting is easily afforded, and thereby to deteriorate in efficiency and in character."

In most communities, appointment of members to the State Public Utility Commission is the most satisfactory method of selection. Appointees should be men of wisdom, deliberation, scientific honesty, judicial temperament, breadth of view, and public spirit, with wide knowledge and experience in business, finance, economics, and public service. Engineering and legal training are best adapted to secure some of these characteristics; but the qualifications mentioned are more essential than such a detail as professional training, and technical service can be secured by the employment of experts. The importance of the benefits accruing to the public justifies ample salaries so as to secure the services of the ablest men. Full power should be given to such a commission to investigate accidents, rates, and service; to make valuations; to require uniform accounts and uniform reports, and control issue of securities and financial management; to

require proper allowance for depreciation; to examine accounts and inspect property; and to make and enforce orders regarding rates, standards, service, and discrimination. Full publicity in all matters is desirable. Future experience will show whether or not it is advisable to include provision for a modified form of the recall, such as is the novel feature of the Connecticut law.

It is still too early to form a final opinion regarding the results of thorough-going regulation of the Wisconsin type; but the tendency toward better service, better feeling between the utilities and the public, more equitable rates, greater stability of securities, and disappearance of discrimination and of corruption of local politics by franchise-seeking companies is unmistakable.

This is a subject of great and growing importance, and one which will in the immediate future come up for legislation in many of the states that have not already taken care of it. The members of this Association, and the Association, are in a position to make a public contribution of great value by taking an active interest in the consideration and development of such legislation, throughout the states in which the membership is active.

DISCUSSION.

Mr. F. Herbert Snow.* Mr. President, I live in a commonwealth where the need of state and national control of public utilities is felt. The control of floods and the conservation of the water resources has to do at one end of the matter with the individual ownership of land and riparian rights, while at the other end it has to deal with affairs involving state rights and the national control.

One of the hopeful signs of the times is the taking out, by common consent, from petty politics of affairs having such extended scope. A large project may be rendered impracticable of accomplishment because of petty hindrances at the roots, where the individual (protected in his rights by laws obscure as to meaning through the practice of the courts varying in different jurisdictions and states) may by wrong political methods direct sentiment in channels to obtain what appears to be the protec-

*Chief Engineer, Pennsylvania Department of Health.

tion of the common interests when, to the contrary, the public benefits are lessened and the development of resources for the common good is prevented.

Some very good projects that should have been municipally owned have been permitted to pass into the hands of private ownership because of despair as to ever making the improvement properly, or of maintaining the improvement thereafter satisfactorily, under municipal control. Again, the opposite has been true. The better citizens of the community were opposed to the passing into the hands of capitalists of the public utility; but through political manipulation public control was lost and the citizens of such communities feel, whether it be justly or unjustly founded, that they are in the hands and grasp of a monopoly.

Speaking with respect to small water-works systems, my observation has been that it is easier and more satisfactory to control a water-works system owned by private capital than to handle and control municipally owned water works. In the former case, the law is less cumbersome and punishment can be inflicted more readily and promptly, while in the latter case there are many obstacles to the successful administration of the law.

Politics cannot be eliminated from public affairs, but they can be toned up considerably. The time has come when reputable citizens of a community should no longer hold aloof from participation in practical politics. If men would stop criticising the conduct of public affairs and instead would participate actively in politics, the result at once would be the fairer and more intelligent discussion of public matters, and more rapid progress in the distribution of benefits where they belong, among the people, would accrue.

Undoubtedly many of you have observed how easy public sentiment can be aroused against the management of privately owned water works. However, capitalists have securities to protect and they must be financially responsible to be worthy of public confidence so far as investments are concerned. If the revenues are not sufficient, bankruptcy follows. With a municipally owned plant deficits can be made up out of general taxation.

The public treasury is a safeguard, and so it is more feasible to do things in connection with a municipally owned system than with a privately owned system.

In New England, where most of the water works are owned by the municipality, the necessity for state regulation and control of the water-works system may not be felt as keenly as in a state where the works are largely owned and operated by capitalists. I believe that the regulation of public utilities should embrace the water-works system regardless of ownership, whether it be a municipal corporation, a private corporation or individual, if the regulation is to take in water works at all.

When we come to the matter of dams and storage reservoirs on streams as a part of the development of the water resources of a district, it is apparent that a great resource like water should not be developed over any extended area except for the benefit of all concerned. It is too true that a few individuals, under the advice of skilled attorneys learned in law, can hold up the development of this great resource until the benefits are directed into the desired channels where a few will profit more in proportion to their interests than will the public.

Conservation and utilization of water resources is a profound subject. It calls for more comprehensive laws and a change in the practice or administration of law. There is such a wide range in the application of legislation affecting rights, that hardly anybody seems to know what to depend upon. The practical result of it all to-day is a great hindrance to the enrichment of the people through the development of this resource. A short cut to proper development of water power and water wealth may be found in state and national control of public utilities dealing in water. It is possible, beginning in the district or the county and extending to the state and national control, to bring all under some practical plan of coöperation. I do not see clearly now how it can be done at this moment; but I believe in the proposition and that it will be worked out. I would not hesitate, were the responsibility placed upon me, to undertake the solution of the problem. Furthermore, I know of other students and men engaged in rubbing up daily against these problems in a minor way, who are inspired with confidence that a solution of the great problem

will be reached along lines under which the interests of the public will be subserved.

Finally, one will not read of failure of dams and the devastation of communities in the valley below, after it has become impossible for any one to build a dam and maintain a reservoir except under the responsible supervision of a competent engineer.

I have labored in my state of Pennsylvania for an organization and unification of engineers, not for the purpose of promulgating trade unionism standards, but for the greater and higher benefit of organization along professional lines. I would make it compulsory on all public works in towns, counties, and state, for a certified engineer to be employed. I would not prohibit the individual from employing whomsoever he might choose up to a certain extent; but I would not permit any incompetent man to have responsible charge of structures or facilities having to do with and involving the safety and lives and the health of the people. It is all right to have the public utility commission and state or central control of public utilities, but without the fixing by statute of the relation between the public and the engineer and without licensure or control to a certain extent of the practice of civil engineering in connection with public utilities, any public utility commission will find itself greatly handicapped in bringing about the greatest good to the greatest number of people.

Believing as I do that I will soon see organization and unification of members of the engineering profession, and that affairs relating to public utilities will by general and common consent be placed under central control, state and national, and that furthermore the people of this land are rapidly coming into their intelligent possession of it through the separation of many practical matters that have no real political significance, but that have up to the present time been prominent considerations in dominating the political parties, I can conclude this rambling discussion by holding up for contemplation a most optimistic view. May we all live and help to make it a speedy consummation!

PROCEEDINGS.

BUZZARDS BAY, June 26, 1912.

The June meeting of the New England Water Works Association was held at Buzzards Bay, Mass., on June 26, 1912.

The following members and guests were present:

MEMBERS.

J. M. Anderson, F. E. Appleton, C. H. Baldwin, L. M. Bancroft, G. W. Batchelder, J. W. Blackmer, E. C. Brooks, James Burnie, T. J. Carmody, J. C. Chase, J. H. Child, R. C. P. Coggeshall, W. R. Conard, G. E. Crowell, A. W. Cuddeback, F. W. Dean, J. C. DeMello, Jr., A. O. Doane, G. F. Evans, E. D. Eldredge, G. H. Finneran, A. N. French, A. S. Glover, Clarence Goldsmith, X. H. Goodnough, J. C. Hammond, Jr., L. M. Hastings, D. A. Heffernan, C. E. Johnson, Willard Kent, G. A. King, J. J. Kirkpatrick, C. A. Leary, T. J. Lynch, T. J. MacCarthy, F. A. McInnes, T. H. McKenzie, C. T. Main, John Mayo, G. F. Merrill, J. W. Moran, A. S. Negus, G. A. Nelson, F. L. Northrop, J. K. Nye, H. E. Perry, E. B. Phelps, W. H. Pitman, L. C. Robinson, A. L. Sawyer, W. E. Smith, G. H. Snell, R. L. Tarr, C. N. Taylor, D. N. Tower, Percy Warren, L. R. Washburn, W. J. Wetherbee, J. C. Whitney, L. J. Wilber, F. B. Wilkins, G. E. Winslow. — 62.

ASSOCIATES.

Harold L. Bond Company, by Geo. S. Hedge; Builders Iron Foundry, by A. B. Coulters; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by A. S. Glover, H. D. Winton; H. Mueller Manufacturing Company, by G. A. Caldwell; Millar & Son Company, by C. F. Glavin; National Meter Company, by C. H. Baldwin, J. G. Lufkin; Norwood Engineering Company, by C. E. Childs; Pittsburg Meter Company, by B. A. Lester; Rensselaer Valve Company, by C. L. Brown, F. S. Bates; Ross Valve Manufacturing Company, by C. W. Ross; A. P. Smith Manufacturing Company, by D. F. O'Brien, T. F. Halpin, F. L. Northrop; Standard Cast Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter Company, by E. M. Shedd; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Water Works Equipment Company, by W. H. Van Winkle; R. D. Wood & Co., by C. R. Wood; Henry R. Worthington, by Samuel Harrison. — 23.

Guests.

Arthur Howland, F. M. Miner, Mrs. E. B. Phelps, Col. C. P. Nutter, W. H. Bacon, S. M. Spencer, A. W. Parker, Miss J. M. Ham, of Boston; Mrs. T. J. Carmody, Miss M. Mann, Miss C. Sullivan, Miss H. Hanley, of Holyoke; Mrs. Geo. E. Winslow, Miss Myra Winslow, Mr. C. H. Mann, of Waltham; Mrs. G. H. Snell, Mrs. Frank Hunnewell, Miss Bertha Hunnewell, of Attleboro; E. W. Hall, West Acton; S. P. Hurd, Swampscott; H. S. Howe, Concord, F. B. Wilkins, Milford, N. H.; Mrs. E. C. Brooks, Cambridge; N. B. Tower, Cohasset; T. Appleton, Chelsea; G. E. Hildreth, Manchester; W. H. Larcom, Beverly; Mrs. L. M. Bancroft, Reading; W. M. Foster, Nashua, N. H.; C. F. Goodnough, Brookline; Raymond Allen, Manchester; John Ayer, Newton Highlands; H. R. Draper, Ayer; Mr. A. S. Ackerman, Mr. Waring, of Cape Cod; F. E. Smith, N. Andover; W. Whittemore, Weston; F. L. Branham, Lowell; C. E. Shattuck, Wellesley; W. J. Turnbull, State Farm; Master Edward H. Eldredge, Onset; Mrs. L. J. Wilber, Brockton; Charles S. Ashley, W. F. Williams, F. H. Taber, F. P. Washburn, C. H. Gifford, New Bedford, Mass. — 48.

The Secretary read applications for membership, duly approved, from: F. C. Beck, treasurer St. Johnsbury Aqueduct Company, St. Johnsbury, Vt.; G. A. Benjamin, manager Castine Water Company, Castine, Me.; J. T. Bowles, physiologist, Canal Zone, Cristobal, C. Z.; J. W. M. Bunker, instructor in sanitary analysis, Harvard University, Cambridge, Mass.; W. M. Davis, city engineer, Prince Rupert, B. C.; E. J. Fossas, student, 524 West 124th Street, New York, N. Y.; G. W. Hubbard, superintendent water works and light plant, Elberton, Ga.; J. J. Mack, 14 Barr Street, Salem, Mass.; J. H. Mendell, superintendent water works, Manchester, N. H.; R. H. Stearns, designing engineer, Board of Water Commissioners, Hartford, Conn.; F. P. Washburn, New Bedford Water Board, New Bedford, Mass.; M. C. Whipple, instructor in sanitary chemistry, Harvard University, Cambridge, Mass.

The Secretary was directed to cast one ballot in favor of the applicants, and he having done so they were declared duly elected members of the Association.

The Thirty-First Annual Convention.

Washington, D. C.,
September 18, 19, 20, 1912.

The thirty-first annual convention of the New England Water Works Association was held at Washington, D. C., September 18, 19, and 20, 1912.

The official headquarters of the Association were at the Congress Hall Hotel, where the sessions of the convention were held and the associate members displayed their exhibits.

The following-named members and guests were in attendance:

Honorary Member.

F. W. Shepperd. — 1.

Members.

S. A. Agnew, E. R. B. Allardice, K. Allen, Dr. J. A. Amyot, J. M. Anderson, M. N. Baker, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, Edward Bartow, G. B. Bassett, G. W. Batchelder, G. A. Benjamin, C. R. Bettes, Philander Betts, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, James Burnie, T. J. Carmody, C. E. Chandler, E. S. Cole, W. R. Conard, J. H. Cook, H. R. Cooper, L. S. Doten, H. P. Eddy, E. D. Eldredge, F. L. Fuller, A. S. Glover, W. B. Goentner, J. M. Goodell, F. E. Hall, Paul Hansen, R. J. Harding, W. C. Hawley, F. S. Hollis, W. C. Hooper, J. L. Hyde, D. D. Jackson, G. G. Kennedy, E. W. Kent, Willard Kent, J. A. Kienle, G. A. King, J. J. Kirkpatrick, F. W. Green, Morris Knowles, B. C. Little, J. B. Longley, T. J. Lynch, Daniel MacDonald, T. H. McKenzie, H. B. Machen, John Mayo, G. F. Merrill, William Murdoch, J. A. Newlands, F. L. Northrop, E. L. Nuebling, T. A. Peirce, A. E. Pickup, W. H. C. Ramsey, J. F. Reagan, Jr., A. A. Reimer, C. H. Ross, H. F. Salmonde, P. R. Sanders, Henry W. Sanderson, J. E. Sheldon, G. H. Snell, J. F. Sprenkel, G. A. Stacy, G. T. Staples, Sydney Smith, J. A. Tilden, J. C. Trautwine, Jr., A. E. Walden, J. H. Walsh, R. S. Weston, G. C. Whipple, L. J. Wilber, G. E. Winslow, I. S. Wood, Walter Wood, Timothy Woodruff. — 88.

Associates.

T. D. Bausher; N. S. Sammis and A. B. Coulters, of Builders' Iron Foundry; R. W. Conrow, Central Foundry Company; F. H. Coffin, F. H. Coffin & Co.; C. J. Fay, Coffin Valve Company; J. L. Hough, Darling Pump and Manufacturing Company; C. A. Vaughan and P. H. Williams, Gamon Meter Company; A. F. Fisher, Glauber Brass Manufacturing Company; C. Mueller

and H. S. Piper, Hays Manufactuing Company; J. A. Tilden, W. C. Sherwood, A. S. Glover, H. C. Erwin, Jr., and E. J. McKee, Hersey Manufacturing Company; T. E. Dwyer, Lead Lined Iron Pipe Company; H. F. Gould, Ludlow Valve Manufacturing Company; C. F. Glavin, Charles Millar & Son Co.; G. A. Caldwell, F. B. Mueller, and C. F. Ford, H. Mueller Manufacturing Company; C. H. Baldwin and J. G. Lufkin, National Meter Company; H. B. Hodgman, National Water Main Cleaning Company; T. D. Faulks, Neptune Meter Company; H. W. Hosford, Norwood Engineering Company; J. B. Turner, T. C. Clifford and V. E. Arnold, Pittsburgh Meter Company; C. L. Brown, Rensselaer Valve Company; William Ross, Ross Valve Manufacturing Company; H. F. Halpin and J. Strackbein, A. P. Smith Manufacturing Company; E. M. Shedd, S. D. Higley, and J. H. Atwell, Thomson Meter Company; L. P. Anderson, Union Water Meter Company; D. B. Stokes, United States Cast Iron Pipe and Foundry Company; W. H. Van Winkle, Water Works Equipment Company; C. R. Wood and H. S. Simons, R. D. Wood & Co.; J. A. Port and Samuel Harrison, Henry R. Worthington; E. F. Bart, National Tube Company; W. F. Woodburn, Standard Cast Iron Pipe and Foundry Company. — 47.

Guests.

Clinton L. Bancroft, Wakefield, Mass.; Mrs. Samuel Harrison, Boston, Mass.; Mrs. F. M. Eayrs, Nashua, N. H.; Miss Ida Flagg, Philadelphia, Pa.; Master Neddie Eldredge, Onset, Mass.; Mrs. C. A. Vaughan, Newark, N. J.; Mrs. George E. Winslow, Waltham, Mass.; Miss Mary Wales Glover, Newton, Mass.; Mrs. Geo. T. Staples, Miss Florence S. Staples, and Miss Grace M. Staples, Dedham, Mass.; Mrs. Geo. A. King, Taunton, Mass.; Miss Margaret Hawley, Wilkinsburg, Pa.; Mrs. John Mayo, Bridgewater, Mass., Mrs. George A. Caldwell, Boston, Mass.; F. P. Hellev, Mrs. F. P. Hellev; and A. E. Leinbach, Reading, Pa.; Mrs. H. N. Hosford, Florence, Mass.; Mrs. L. J. Wilbur, Brockton, Mass.; Mrs. George H. Snell, Attleboro, Mass.; Miss Edith M. States, Attleboro, Mass.; Mrs. John H. Cook, Passaic, N. J.; Mrs. F. L. Fuller, Wellesley, Mass.; Mrs. R. J. Harding, Poughkeepsie, N. Y.; Robert W. Grout, Woonsocket, R. I.; Mrs. F. W. Shepperd, New York; Mrs. T. F. Halpin and Miss Mary Smith, Newark, N. J.; L. D. Conklin, Bethlehem, Pa.; A. R. McKlin, Albany, N. Y.; Mrs. James Burnie and Miss Helen M. Burnie, Biddeford, Me.; Mrs. N. R. Cooper, Thompsonville, Conn.; Geo. C. More and Mrs. Geo. C. More, Middletown, Conn.; J. P. Newman, New York City; J. S. Biszby, Moorestown, N. J.; Mrs. W. B. Goentner, New York; S. C. Mackley, Roanoke, Va.; L. M. Hills, Mrs. L. M. Hills, and Mrs. E. R. B. Allardice, Clinton, Mass.; A. W. Warner, Philadelphia, Pa.; Mrs. E. W. Kent, Newport, R. I.; W. H. V. Reimer, Mrs. W. H. V. Reimer, and Miss I. A. Reimer, East Orange, N. J.; James L. Wilde, Washington, D. C.; James P. Bacon, Arlington, Mass.; William H. Larcom, Beverly, Mass.; Mrs. C. E. Chandler, Norwich, Conn.; Mrs. George A. Stacy, Marlboro, Mass.; Willard S. Isham, Washington, D. C.; May I. Agnew, Brook-

lyn, N. Y.; Mrs. Irving S. Wood, Providence, R. I.; Mrs. T. A. Pierce and Mrs. Emma A. Vaughan, East Greenwich, R. I.; Edgar J. Buttenheim, *The American City*, New York; Henry Gannett, Washington, D. C.; Farley Gannett, Harrisburg, Pa.; Mrs. George A. Benjamin, Castine, Me.; W. F. Disney, Rockville, Md.; Agnes C. Babb, Augusta, Me.; Adam Ross, 2d, Troy, N. Y.; Phillip P. Wells, Washington, D. C.; F. J. Wise, Pittsfield, Mass.; William McSweeney, Boston, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; William T. Wells, Washington, D. C.; Andrew E. Barrett, Lowell, Mass.; Mrs. Thomas J. Carmody, Miss Elizabeth Lynch, Miss Maria Maria, and Mrs. Walter Hanley, Holyoke, Mass.; Edward K. Otis, Worcester, Mass.; H. C. Hatton, Wilmington, Del.; W. J. Dodge, Chattanooga, Tenn.; A. Clinton Decker, Birmingham, Ala.; R. L. Clemmitt and Miss Frances E. Allen, Baltimore, Md.; H. D. Yat, Washington, D. C.; Fred W. Schultz, New York; Miss Joan M. Ham, Boston, Mass. — 85.

WEDNESDAY, SEPTEMBER 18, MORNING SESSION.

The convention was called to order at 10.30 A.M. by George W. Batchelder, the President, who said:

Ladies and Gentlemen of the New England Water Works Association, — I trust that the convention which opens this morning will be a source of profit and enjoyment to you all. We are meeting many miles away from our headquarters in Boston, and, lest we should feel like strangers in a strange land, a distinguished gentleman has consented to speak words of welcome to us. I take pleasure in presenting to you at this time Col. William V. Judson, engineer commissioner of the District of Columbia.

COLONEL JUDSON. *Gentlemen,* It is a great privilege to supply communities with a product against which there is no prejudice — to use which liberally is not to be extravagant but to insure health and cleanliness.

In introducing so many springs of limpid water into the dwellings of men you are doing or facilitating the things that most differentiate the life of civilized man from the life of the savage.

From the modern scheme of things you could be spared least of all.

If communities depend upon you for the exercise of so all-important a function, your responsibility is great indeed. The satisfied purveyor of water that carries to people the germs of disease and death merits the punishment awarded to the homicide.

I know some of your worries. Especially at the present time,

when we have just raised our water rates, am I brought to realize the extreme reluctance people exhibit to pay a fair price for water.

Gentlemen, in behalf of the District Commissioners I welcome you to Washington. I hope you will forget worries of all kinds and enjoy your stay with us.

THE PRESIDENT. Colonel Judson, in behalf of the Association, I wish to thank you for your cordial and hearty words of welcome. I am sorry that you have so much trouble on your mind, but you don't show it a great deal, and I think you will pull through. We would like very much to have you stay with us as long as you find it convenient, at the meeting to-day or at any future meetings while we are in your city. We expect to go away with pleasant recollections of Washington, and we may come back again at some future time.

The Secretary read the following names of applicants for membership, all of whom had been properly endorsed and approved by the Executive Committee:

Active: Daniel Francis McCarthy, city engineer and superintendent of streets, sewers, and water works, St. Albans, Vt.; George Neut, chief engineer of water works, Santiago, Chili; Charles R. Harris, Portland, Me., bookkeeper Portland Water Company; Langdon Pearse, Chicago, Ill., division engineer, Sewage Disposal Investigations, Sanitary District of Chicago; A. S. Malcomson, Freeport, N. Y., general manager of the Hempstead and Oyster Bay Water Company of Merrick, Long Island.

Associate: Thomas D. Bausher, Reading, Pa., inventor and maker of kindling and fuel, water works and plumbers' furnaces, thawing furnaces for frozen earth, heating furnaces for orchards, icy sidewalks, and other devices; National Tube Company, Pittsburgh, Pa., manufacturer of pipe fittings, valves, seamless tubing, etc.

On motion of Mr. Frank L. Fuller, the Secretary was empowered to cast the ballot of the Association in favor of the candidates, and, he having done so, they were declared by the President duly elected members of the Association.

The Secretary read the following reports of committees:

September 14, 1912.

Mr. Willard Kent,
Secretary New England Water Works Association,
715 Tremont Temple, Boston, Mass.

Dear Sir, — The Committee on Yield of Drainage Areas is unable to make a final report at this time. The returns covering the dry period, which in some places extended from June, 1908, to February, 1912, have been received from twelve drainage areas, five located in Massachusetts, one in New Hampshire, two in Connecticut, and four in the easterly portion of New York.

Extended computations and comparisons have been made relating to these drainage areas, which show that the investigation will throw much light on the safe yield from streams in different locations with varying quantities of storage. The material already available is sufficient for a report, but it is expected that more returns will be received before our final report is made. We hope to present this final report at the annual meeting in January.

Very truly yours,
Frederic P. Stearns, *Chairman.*
H. H. Barrows, *Secretary.*

August 16, 1912.

Mr. Willard Kent,
Secretary N. E. W. W. Ass'n,
715 Tremont Temple, Boston.

Dear Sir, — I beg to report for the Committee on "Standard Form of Specifications for Cast-Iron Water Pipe and Special Castings" that no meetings have yet been held, the work done up to date being confined entirely to individual consideration of the subject.

Respectfully,
F. A. McInnes, *Chairman.*

Boston, Mass., August 14, 1912.

Willard Kent, *Secretary,*
New England Water Works Association,
715 Tremont Temple, Boston, Mass.

Dear Sir, — About the time your letter was received negotiations were under way with the hydrant manufacturers for sample hydrants for test for the information of the committee in connection with the hydrant specifications, which are still under consideration, and we held your letter thinking that a little later we might be able to know definitely just when the tests would be made.

We are pleased to say that arrangements have been completed for the hydrants, and we expect that these will be shipped to the testing ground within the next week or two. This, however, will not be in time to permit the tests to be completed and the committee to reach final conclusions regarding the

specifications before the September convention of the Association, and it will, therefore, be necessary to delay report until a later meeting.

Yours truly,

H. O. LACOUNT, *Chairman.*

To the Members of the New England Water Works Association, — Your Committee on Water Consumption Records and Statistics regrets its inability to make final report at this time, and asks to be continued.

Substantial progress has been made in collecting data of value concerning water consumption, in different cities in New England, and under different conditions. Your committee is now working these data up, and is considering the most desirable revision of the form now used by the Association for collecting statistics annually from the various water works and departments represented by the members of this Association.

Respectfully submitted,

LEONARD METCALF, *Chairman.*

The President announced that the reports, being merely reports of progress, did not require any action on the part of the meeting. The next business was the appointment of a committee to nominate officers for the ensuing year. Mr. George A. Stacy moved that a nominating committee of five be appointed by the chair. The motion was adopted. The President subsequently appointed the following committee: John C. Whitney, Frank A. Barbour, Arthur F. Ballou, Frederick W. Gow, and Robert J. Thomas.

The first paper on the program was on "State Control of the Design and Construction of Dams and Reservoirs; Actual Practice in Eastern Connecticut," by Charles E. Chandler, C.E., Norwich, Conn. The President called upon the following-named gentlemen to discuss the paper: Mr. P. P. Wells, chief law officer of the Interior Department; Prof. Philander Betts, member of the New Jersey Public Utilities Commission; and Mr. Alex Rice McKim, inspector of dams and docks, State Conservation Commission, Albany, N. Y. Mr. Theodore H. McKenzie, C.E., member of the Connecticut State Board of Health, and secretary and treasurer of the Terryville Water Company, Southington, Conn., also contributed a written discussion of the paper.

Mr. Cyrus C. Babb, chief engineer Water Storage Commission of Maine, Augusta, Me., read a paper entitled "Certain Legal Aspects of Water Power Development in Maine." Mr. Morris

Knowles, C.E., director Department of Sanitary Engineering, University of Pittsburgh, Pa., followed with a written discussion of the paper, which was also discussed by Mr. P. P. Wells, Professor Betts, and Mr. Arthur A. Reimer, engineer Water Department, East Orange, N. J.

A paper on "State Control of Dams in Pennsylvania," by Prof. Frank P. McKibben, of Lehigh University, South Bethlehem, Pa., was read by Mr. Leon D. Conkling, and was discussed by Mr. John C. Trautwine, Jr.

Thursday, September 19, Morning Session.

At the opening of the session on Thursday morning, Mr. T. Chalkley Hatton, the designer of the dam at Austin, Pa., read a paper presenting some features of the construction and subsequent failure of the work; and Mr. John C. Trautwine, Jr., spoke on the same subject.

A paper entitled, "Reasonable Requirements Imposed upon Water Works Systems by the Fire Protection Problem," by Mr. Clarence Goldsmith, C.E., superintendent of high pressure system, Boston, Mass., was read by Mr. McSweeney, and was briefly discussed by Mr. Frank L. Fuller and Mr. W. C. Hawley.

Mr. George A. Stacy.* *Mr. President*, I would like at this time to ask the convention to digress from the regular order of business, for I believe that what I have to say will be of interest to all of you.

As we look around upon the faces of the gentlemen present at this convention, we miss one face that has been familiar for many years to the older members of the Association at our meetings. There passed on, a week ago last Monday, a past President of this Association, who has been closely identified with its progress and prosperity. I believe that we owe it as a duty to the memory of this man at this time to recognize his many qualities that stood for good, and the interest that he always manifested not only in the Association but in its individual members.

Who is there of us who does not remember with pleasure the greeting that always came to us from Past-President Charles K.

* Superintendent Water Works, Marlboro, Mass.

Walker. It was genuine. We knew that it came from the heart, and whether you met him at one of our meetings, or at his home, or on the street, or in his office, he was the same thoroughly honest man, whose integrity was as unquestioned as the stability of the hills of his own state. He was a man of sterling character, modest and unassuming in his demeanor, but firm as a rock in maintaining what he considered the right position. In discussion, Walker was fearless and struck straight from the shoulder. This was due to the rugged honesty of his character and to no malice in his heart, because no man ever had a kinder heart than our past President.

Now, gentlemen, I would suggest that you all rise and join with me in this sentiment: May our memory of him be always fresh and green. May his few faults be forgotten and his many virtues blest. Amen.

Mr. Robert S. Weston, in behalf of the officers of the Sanitary Engineers Section of the American Public Health Association, extended an invitation to the members of the Water Works Association to attend a meeting of the Health Association, to be held for the consideration of the general subject of the pollution of rivers and other streams. He also called attention to the exhibition of models of water purification plants, etc., in connection with the Fifteenth International Congress on Hygiene and Demography. In behalf of the Association the President thanked Mr. Weston for the invitations.

Mr. M. N. Baker announced that as chairman of the Conservation Committee of the Association he had received a letter from the president of the Fourth National Conservation Congress requesting the Association to appoint a delegation to attend the Congress to be held at Indianapolis in October, and that the name of Mr. F. S. Hollis, of Indianapolis, had been suggested by the Secretary as a delegate. Mr. Baker therefore moved that Mr. Hollis be accredited by the Association to attend the Congress, and the motion was adopted.

Evening Session.

At the evening session Mr. Morris Knowles, director Department of Sanitary Engineering, University of Pittsburgh, Pa., read a paper entitled "State Regulation of Public Utilities."

Mr. E. C. Church, C.E., secretary Department of Water Supply, Gas, and Electricity, New York, N. Y., gave an outline of "The Organization and Administration of a Supply Bureau."

Mr. M. O. Leighton, chief hydrographer United States Geological Survey, and Mr. F. Herbert Snow, chief engineer of the Pennsylvania Department of Health, discussed the general subject of governmental control of dams and public utilities; and Mr. Babb replied to the discussions of the paper presented by him at the Wednesday morning session.

The following-named gentlemen were elected members of the Association, on motion of Mr. Morris Knowles, the Secretary having been directed to cast the ballot of the Association in their favor:

Active: F. Herbert Snow, Pittsburgh, Pa., chief engineer State Department of Health; Fred J. Wise, Pittsfield, Mass., superintendent of water works.

Associate: Carroll Beale, Washington, D. C., manufacturer of self-operating valves and designer of water works; A. R. Murphy, assistant engineer with John A. & Edward S. Cole.

The Secretary announced that the committee had made no special arrangements for the morrow, but that Mr. W. A. McFarland, of the Washington Water Department, invited the members to inspect his plant and would have his organization ready to show any part of the water system they desired to see.

The Secretary read the following report of the Committee on Exhibits, which was accepted:

Washington, D. C., September 19, 1912.

Mr. President and Members of New England Water Works Association, — I take pleasure in submitting my report as to the exhibits displayed here for the inspection of our members.

The representatives of the various manufacturers wish to express their pleasure at the interest shown by those inspecting their goods.

The following are represented:

The Pitometer Company, of New York, water measuring device.

Coffin Valve Company, of Boston, Mass., valves and sluice gates.

Ross Valve Manufacturing Company, of Troy, N. Y., high pressure fire hydrants, water regulating devices.

Pittsburg Meter Company, of East Pittsburg, Keystone and Eureka meters.

T. D. Bausher, of Reading, Pa., lead furnaces and fuel.

Union Meter Company, of Worcester, Mass., water meters and brass goods.

Geo. H. Snell, of Attleboro, Mass., pipe couplings.

Geo. H. Staples, of Dedham, Mass., service pipe cleaner.

Self-Operating Valve Company, of Washington, D. C., hydraulic valve operator.

Gamon Meter Company, of Newark, N. J., Watch Dog meters.

Lead Lined Iron Pipe Company, of Wakefield, Mass., lead and tin lined iron pipe and fittings.

Water Works Equipment Company, of New York, water works appliances.

R. D. Wood & Co., of Philadelphia, fire hydrants and "Reduced Specials."

Henry R. Worthington, of New York, water meters.

Hays Manufacturing Company, of Erie, Pa., tapping machines, service boxes, brass goods, and water works appliances.

Thomson Meter Company, of Brooklyn, N. Y., Lambert meters.

Francis H. Coffin, of Scranton, Pa., wooden pipe.

H. Mueller Manufacturing Company, of Decatur, Ill., meter testing machine, tapping machines, flushing hydrant, brass goods, and water works appliances.

National Water Main Cleaning Company, of New York, turbine water main cleaner.

Builders Iron Foundry, of Providence, R. I., Venturi meters, gages and meter boxes.

Hersey Manufacturing Company, of South Boston, Mass., water meters, detector meters.

Glauber Brass Manufacturing Company, of Cleveland, Ohio, water works brass goods.

National Tube Company, of Pittsburg, Pa., "Kewanee" unions, valves, and fittings.

National Meter Company, of New York, Empire, Crown, Nash, and Ajax meters.

A. P. Smith Manufacturing Company, of East Orange, N. J., tapping machines, brass goods, sleeves, fire hydrants, gate valves, and water works appliances.

Norwood Engineering Company, of Florence, Mass., mechanical filters.

Standard Cast-Iron Pipe and Foundry Company, of Bristol, Pa., and Malden, Mass., cast-iron bell and spigot pipe, cast-iron flange pipe, bell and spigot and flanged fittings.

Central Foundry Company, of New York, universal joints.
Engineering Record.
Fire and Water Engineering.
Engineering News.
The American City.

Respectfully submitted,

WM. F. WOODBURN,
Chairman Committee on Exhibits.

THE PRESIDENT. Is there any other business?

MR. SAMUEL A. AGNEW. I think we ought at this time to express our appreciation to the gentlemen who have contributed so largely to the success of our convention. I therefore move that a vote of thanks be extended to the several gentlemen who have presented papers here and to those gentlemen who have entered into the discussion of them; also to the Committee on Entertainment, Mr. McFarland and Mr. Stokes, and to Mr. Woodburn, who has had charge of the exhibits. Adopted.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at Buzzards Bay, Wednesday, June 26, 1912.

Present: President George W. Batchelder, and members Frank A. McInnes, George A. King, Lewis M. Bancroft, and Willard Kent.

Twelve applications were received and recommended for membership, namely:

For members: F. C. Beck, treasurer St. Johnsbury Aqueduct Company, St. Johnsbury, Vt.; G. A. Benjamin, manager Castine Water Company, Castine, Me.; J. T. B. Bowles, physiologist, Canal Zone, Cristobal, C. Z.; J. W. M. Bunker, instructor in sanitary analysis, Harvard University, Cambridge, Mass.; W. M. Davis, city engineer, Prince Rupert, B. C.; E. J. Fossas, student, 524 West 124th Street, New York, N. Y.; G. W. Hubbard, superintendent water works and light plant, Elberton, Ga.; J. J. Mack, 14 Barr Street, Salem, Mass.; J. H. Mendell, superintendent water works, Manchester, N. H.; R. H. Stearns, designing engineer, Board of Water Commissioners, Hartford, Conn.; F. P. Washburn, member New Bedford Water Board, New Bedford, Mass.; M. C. Whipple instructor in sanitary chemistry, Harvard University, Cambridge, Mass.

Voted, that the headquarters of the Association for the annual convention of the present year, in Washington, D. C., be established at the Congress Hall Hotel.

Voted, that William F. Woodburn, of Malden, Mass., be the Committee on Exhibits for the September Convention.

Voted, that President Batchelder, W. A. McFarland, and D. B. Stokes be the Committee of Arrangements for the Annual Convention.

Voted, that but three sessions be held during the Convention, namely, from 10.30 A.M. to 1 o'clock P.M. on Wednesday and

Thursday and one on Thursday evening, and that Friday be devoted to an excursion to Mount Vernon and Arlington.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at Congress Hall Hotel, Washington, D. C., Wednesday, September 18, 1912, at 10 o'clock A.M.

Present, President George W. Batchelder, John H. Cook, George A. Stacy, Lewis M. Bancroft, George A. King, and Willard Kent.

Seven applications were received and recommended for membership, namely:

For membership: Daniel F. McCarthy, chief engineer, Lawrence Park Realty Company, Bronxville, N. Y.; Charles R. Harris, Portland, Me.; Langdon Pearse, division engineer, Sewage Disposal Investigations, Sanitary District of Chicago, Chicago, Ill.; A. S. Malcomson, general manager of Hempstead and Oyster Bay Water Company, of Merrick (Long Island), Freeport, L. I., N. Y., George Neut, chief engineer, Empress de Aqua Potable, Santiago, Chili.

For associate membership: Thomas D. Bausher, water works and plumbers' furnaces, Reading, Pa.; National Tube Company, manufacturers pipe fittings, valves, etc., Pittsburgh, Pa.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at Congress Hall Hotel, Washington, D. C., September 19, 1912, at 7.30 o'clock P.M.

Present, President George W. Batchelder, John H. Cook, George A. Stacy, Lewis M. Bancroft, George A. King, and Willard Kent.

Applications of the following named persons were approved and recommended to the Association for election to membership:

For membership: F. Herbert Snow, chief engineer, State Department of Health of Pennsylvania, Harrisburg, Pa.; Fred J. Wise, superintendent water works, Pittsfield, Mass.

For associate membership: Carroll Beale, manufacturer of self-operating valves and designer of water works, Washington, D. C.

Adjourned.

Willard Kent, *Secretary.*

OBITUARY.*

Charles Kimball Walker was a native of Manchester, N. H. He was born on June 18, 1830. His home at 68 South Main Street, West Manchester, had been his residence throughout his entire life of more than eighty-two years.

After receiving the instruction offered by the district schools of those days, and when still a boy, he took up studies in the direction of civil engineering. At the age of twenty, he was employed in the survey for the Concord & Montreal Railroad. After three years' service, he assisted in the survey of the Wilton Railroad.

In 1852 he married Miss Ann Maria Stevens, of Wentworth, and immediately thereafter removed to New York, where he followed his profession on the New York & Erie Railroad. Later he was engaged on the Marietta & Cincinnati Railroad. Upon the completion of these enterprises, Mr. Walker returned to his Manchester home and very soon we find him employed on the Suncook Valley Railroad under the late Ex-Governor James A. Weston, who was his lifelong personal friend. He was also of the engineering corps of the East Jaffrey Railroad, the Lowell and Farmington, Hopkinton, and Montpelier and Wells River.

A little later he was employed in the surveys for the Manchester Water Works, and after its completion was in 1875 elected superintendent, and he continued to fill this position without a break until the first day of April of the present year, when he tendered his resignation. He had been in failing health for some time, his decline being gradual, and after he relinquished his activities, he gradually became more inactive, until at last he was prostrated by a shock and the end came on September 9. Mr. Walker is survived by his wife and two daughters.

Charles K. Walker was a true son of New Hampshire. He loved her rugged and picturesque hills and he seemed to imbibe

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* Memoir prepared by R. C. P. Coggeshall.

something of their rough beauty in his nature. His principles of right and wrong were based upon as solid a foundation as those of the everlasting hills amid which he loved to roam. He stood squarely for those things which were honest, just, and of good report. While brusque and quaint of speech, and exceedingly frank in expressing his opinions, yet he never left a sting in the minds of those whom he addressed. On the contrary, the impression was generally whimsical, bright, and witty. Many pages could be written of the quaint sayings of our friend which under the guise of wit contain a lot of "horse sense." He greatly disliked the jarring notes of life and did everything he could to prevent their appearance.

I think that perhaps his best work in this Association was in the direction of smoothing out the angles of strife whenever they appeared. He was a master in doing that. He dearly loved this Association and he was active in its affairs from its very beginnings. When about twenty men, all strangers to each other, gathered at Young's Hotel, Boston, April 19, 1882, to consider the formation of this society, Mr. Walker was there and did much to relax the strain incidental to the meeting of a body of strangers. We all left that meeting feeling that we had found a new friend in him. He was a constant attendant of the meetings through all the long term of years and frequently took part in the discussions and debates, and his message was always acceptable. He served the Association fifteen terms as one of its vice-presidents and in 1903 he was its president.

His memory remains with those who knew him best as that of a beautiful yesterday which has passed by.

New England Water Works Association.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

REASONABLE REQUIREMENTS IMPOSED UPON WATER WORKS SYSTEMS BY THE FIRE PROTECTION PROBLEM.

BY CLARENCE GOLDSMITH, ASSISTANT ENGINEER, PUBLIC WORKS DEPARTMENT, BOSTON, MASS.

[*Read September 19, 1912.*]

In any water-works system the requirements imposed by the fire protection problem have very much in common with those involved in furnishing an adequate and reliable domestic supply.

The success of any enterprise is dependent upon its financial resources and the organization of its working force. Under ordinary conditions a per capita expense of from thirty dollars to forty dollars is necessary to develop an adequate water-works system. Climatic and topographic conditions, however, are the controlling factors, and in localities where expensive water rights have to be acquired, or where a wide range in elevation exists, the expense may increase to about double the above-named figures.

One of the fundamental difficulties encountered in properly developing a water-works system is the securing of necessary funds to develop the works in advance of the increase in consumption. In some cases this difficulty is due to lack of confidence in the engineering ability of the department, and in others to political reasons. No money is ever saved by postponing a proper development, for in nearly every case the delay causes a large

loss by necessitating a temporary construction which is comparatively useless in the regular development of the works, besides subjecting the inhabitants to extreme inconvenience, and perhaps exposing the city to epidemic and conflagration.

Instances of dilatory tactics in financing necessary developments are, unfortunately, too numerous; in fact, a large proportion of our cities outgrow their supplies or equipment before the necessary additions are made. For example, the city of Lawrence, Mass., was warned early in 1900 that the consumption had reached the winter capacity of the filter beds, which at that time were not covered. Yet no money was placed at the disposal of the water board until 1906, when a new covered filter was contracted for, but not in time for construction work to be completed before the cold weather set in. The supply available from the old filter was so seriously depleted during the exceptionally cold weather of December of that year and the following month that early in February not more than one million gallons of water was available in the reservoir. At this time relief was afforded by water supplied from the mains of adjoining towns. If a large fire had occurred during the period of low water in the reservoir, it would have been necessary to take suction from the river, which is highly polluted with sewage, in which case an epidemic of typhoid fever would have been inevitable.

As a second example, the city of Worcester, Mass., may be cited, for we are all familiar with the conditions existing in that city during the summer of 1911, as described in the paper read before this Association by Mr. Frank C. Kimball.*

In 1902, the necessity of starting the development of the Asnebumskit supply was apparent to those who were acquainted with the needs of the city, and though Mr. Batchelder, our President, worked very strenuously each year during the intervening period to secure the necessary funds to prosecute this work, no considerable money was provided until 1911, and the result is well known.

The city of Detroit is to-day confronted by a lack of capacity in its pumping station and distributing mains.

I want to call your attention to a fact interesting to you all,

* JOURNAL N. E. W. W. A., Vol. XXVI, p. 113.

which, without doubt, has a deeper influence on the results obtained by our municipal works than one would at first suppose, and that is the small salaries paid to water-works superintendents and engineers. What private corporation capitalized at from two to five million dollars would for an instant try to secure a man to direct every detail of the business for the paltry salary of from \$1 800 to \$3 000 a year? Yet this is what a superintendent is expected to do in a water-works system of the class above mentioned, for a wise board of commissioners will always be guided by the opinion of its superintendent in all matters pertaining to the operation and development of the works. It is to be hoped that in these days, when efficiency is the watchword, and the operation of all city departments is more carefully scrutinized than formerly by the citizens, the advisability of securing and keeping in office capable men, and adequately recompensing them, will be recognized.

Of all the various methods of organization in vogue in the different municipalities throughout the country, no single one can be selected as a panacea. The trend of the times is to centralize authority, which is accomplished by the commission form of government and modifications of it. This method, unfortunately, does not assure the securing of properly trained men for the positions, and although the recall may be applied, it is doubtful if a second selection would be an improvement on the first. The great trouble is that so many water-works positions have been and are now being filled by men with no previous experience or training along such lines, and who attain and retain their positions through political influence, that the public is apt to be misled into the belief that any one can run a water-works system. Such an assumption is untenable, and appears absurd upon even a casual study of the question.

This undesirable state of affairs is being met by the adoption of civil service rules in many cities, and if the examinations are properly and impartially conducted, good results are bound to be obtained. Many works are operated satisfactorily under the direction of a board of water commissioners, and this method has much to recommend it. When composed of three or more members, the term of one expiring each year, such a board assures a

continuity of purpose, and a new member who has been most antagonistic toward certain policies of the board may become an ardent supporter of these policies after he has had an opportunity to study the situation at short range. Nevertheless, the ever-present danger of incompetence confronts us in this case as well as in the former, and works which have flourished long under boards of water commissioners may become suddenly disorganized through the election or appointment of men subservient to political influences and more concerned about private well-being than public welfare. One must conclude from the various examples that constantly come to our attention that the responsibility reverts to the mass of citizens who control the situation by their votes, and that progress toward a more businesslike control of water-works plants must be brought about by a campaign of education. Civil service as applied to employees has many good points in its favor. It secures long terms of service for employees and relieves in a great measure those in authority from the importunities of those seeking positions for themselves or for others. The desirability of not changing employees is equally important from the standpoint of domestic supply and fire protection. Much of the work of operation is accomplished by laborers who through years of experience have acquired skill and knowledge in their work, which is almost indispensable in cases of emergency. Yet there are some cities in which the department undergoes a complete change of personnel at intervals of two years.

In order to enable the employees, when well organized, to render prompt and adequate service, complete records, properly filed, and suitable quarters are necessary. A detailed discussion of the subject of records is impossible in a paper of this character, but because of its great importance, those most essential are here briefly referred to:

A skeleton map of the distribution system on a scale of about 1 in. to 500 ft., showing mains, gates, and hydrants, is of great use for reference purposes, and of particular value in making studies for the extension or reinforcement of the distribution system.

Detailed locations in plat form on a scale of about 1 in. to 40 ft., showing mains, gates, and hydrants, are indispensable, and it is

convenient in many cases to show service connections on these sheets as well.

Records of service connections, gates, hydrants, and meter locations should be arranged in card index form.

The location of gates on the distribution system and those on services larger than two inches in diameter should be arranged in convenient form for ready reference, and copies of these records should be supplied to all employees authorized to operate gates.

Records of pumpage or delivery of flow lines, as made by one of the several accurate continuous-recording devices now on the market, should be kept, and the pumping station records should show the complete performance of the equipment.

Records of pressure maintained at several points of the system should be secured by the installation of recording pressure gages.

The above-mentioned records, together with such necessary and desirable amplifications as may be called for, should be kept up to date. The more important plans and records should be in duplicate, and one set should be stored in a substantial fireproof vault. The question of guarding records against destruction by fire cannot be too strongly emphasized, and it is to be regretted that it is a subject which is often completely or partially neglected. The ordinary fireproof vault is of questionable efficiency in a conflagration, and in many cities it is the custom to provide safe storage at the supply works, but removed from the danger of sweeping fires.

The engineering office, which generally occupies a building in common with the executive and clerical forces, should have ample area for carrying on the maximum amount of work which is liable to devolve upon this branch of the service during periods of active construction. The room or rooms should be properly ventilated and supplied with both natural and artificial light. Partitions should be so constructed that the occupants shall not be subject to the intrusion of the public, or other distraction. Well-arranged filing cases and vaults should be readily available for the storing of all plans and records. A library should be provided which should contain the latest editions of the most desirable handbooks and scientific works bearing on the various subjects which have

to be dealt with in the design, construction, and operation of a water-works system, and in addition a file of the best engineering magazines should be available, so that the working force may keep in touch with work of a nature similar to their own carried on in other cities.

The storage yard, usually containing a repair shop and stable, should be of ample area, and so located that shipments of material may be conveniently and economically handled both from the cars and in the area covered by the distribution system. The yard should be so laid out with paved drives that all the stock shall be readily accessible, and chain falls, with either derricks or cranes, should be provided for handling the heavier pieces. Fittings, valves, and hydrants may well be kept in covered sheds. If the yard is located in a closely built-up district, it is particularly desirable that the buildings be of fireproof construction; otherwise, they should be equipped with sprinklers, standpipes, and hose. The shop should contain tools of the kinds and sizes required to do all but the heavier repair work, and particular attention should be paid to the lay-out of the meter repairing and testing rooms. The offices of the several branches of the work should be connected by telephone, and constant watch should be maintained at the repair shop in all cities having a population of over fifty thousand. The requirements mentioned thus far are necessary for the construction and maintenance of a water-works plant furnishing a reliable domestic supply.

Fire alarms should be received over the gong or tapper circuit of the fire-alarm system in one or more offices of the department, and at least one employee familiar with the distribution system and prepared to operate gates should respond to all first alarms in mercantile and manufacturing districts, and second alarms elsewhere. Provision in duplicate should be made for notifying the pumping station of alarms.

The experience of many departments, as well as of public service corporations engaged in similar work, is that the motor-driven vehicle has become a necessary adjunct to the equipment of every water-works system. It enables a prompt response in case of accident, and increases the efficiency not only of the executive force, but also of the laborers in many branches of the work.

There is hardly a plant of any magnitude on which one or more automobiles cannot be profitably operated.

The source of supply must be carefully studied before its adequacy from the fire protection standpoint can be determined with certainty. The total quantity of water used for the extinguishment of fires is proportionately very small, being approximately one tenth of a gallon per capita per day, or in round numbers about one thousandth of the total consumption, but for short periods of time the rate is very high. From a perusal of the consumption records of any well-operated works, the maximum hourly, daily, and monthly rates can be readily determined, and from a study of the structural conditions in the city — areas, heights, protected openings, exposures, occupancies, construction of buildings, etc. — the probable maximum quantity which would be required to combat a fire of large proportions can be estimated within reasonable limits. The number of fire streams required simultaneously in cities of average character has been discussed by our leading hydraulic engineers, with practical unanimity of opinion. Their estimates are based on actual practice, and the values given by Mr. Kuichling are expressed by the formula $Y = 2.8\sqrt{x}$, where Y equals the number of 250 gal. streams and x equals the population in thousands. This formula does not make any allowance for broken services, and should be applied only after a study of the local conditions has been made, for in many cities the size of the mercantile or manufacturing districts is not in proportion to the population. A very full discussion of this subject was presented to the American Water-Works Association last year by Messrs. Metcalf, Kuichling, and Hawley.* Although the chance of a large fire occurring during the hours of maximum consumption is somewhat improbable, nevertheless it is wise to err on the safe side, and to use the maximum hourly consumption figure in the calculations, although in most cases the maximum daily rate may be used with comparative safety. This step is not so unreasonable as at first appears, for any city should have its supply developed somewhat in advance of present requirements, in order to care for future growth. In cities not exceeding one hundred thousand in population, where the lawn-

*Proc. Am. W. W. Assoc., 1911, p. 55.

sprinkling is restricted to certain periods of the day, it is feasible to enforce an ordinance prohibiting irrigation during the progress of a fire, thus materially reducing the maximum rate for which the city would otherwise have to provide. In some cities, dependent upon fire engines, the pressure is so reduced by large fire drafts that the domestic consumption rate will drop appreciably. Such distribution systems cannot, however, be considered adequate for the service required of them.

There are many cities located on large lakes and rivers where a practically unlimited supply is available, and one does not have to give the question a thought, but in others it is a most important question with the engineer. In these latter the problem is varied, but resolves itself into some method of storage so that the maximum rates can be delivered to the distribution system. If the supply is derived from driven wells, they should be so developed as to furnish the maximum daily rate, and the maximum hourly and fire-flow rates may economically be cared for by storage in a covered reservoir available for delivering into the distribution system. If the supply is derived from storage from a large catchment area, the capacity of this storage should be ample to meet the demands made upon it through a series of dry years. In dealing with such a supply, the average daily consumption, and not the varying hourly rates, must be considered in determining the minimum capacity of the storage reservoirs.

The source of supply having been determined, the method of delivery to the distribution system confronts us. In many cases where the supply is derived from rivers and lakes, and generally when delivered from storage reservoirs, these sources are at an elevation sufficient to deliver the supply by gravity. In a few cases the topography of the country is such that the sources of supply are in close proximity to the distribution system, but in by far the greater number they are at some distance. In the latter cases, distributing reservoirs within or near the area served by the distribution system become an economical necessity, for their existence permits the use of much smaller conduit lines. These lines should have a capacity at least equal to the maximum daily consumption, and one such line cannot be depended upon unless the storage in the distributing reservoir is ample to furnish

the supply during the longest period that will be required to make repairs. The conduits delivering the Catskill supply to the city of New York, the Owens River supply to Los Angeles, and the Wachusett supply to the Metropolitan District of Boston, are not in duplicate, but the permanency of their construction and the storage provided along their routes and at their termini assures the continuity of the supply. On systems where there is more than one supply line, these lines should not follow the same route, as the failure of one may cause the failure of another, or both may be put out of service at the same time from the same cause, as was recently the case in Seattle, Wash. Where pumps are required to deliver the supply to the distribution system, the pumping station should be of fireproof construction. No valid excuse can be offered for not constructing stations absolutely fireproof. The installation of sprinkler equipment, standpipes equipped with hose, and chemical extinguishers, in the many existing stations which are not fireproof, should be strongly advocated. In all cases, oil should be stored outside the building, and all internal hazards should be reduced to a minimum. When stations are exposed to external hazards, outside sprinklers, water curtains, and wire-glass windows should be provided. On buildings having incombustible roof coverings and cornices these give reasonable protection.

The selection of the equipment of the station requires careful study in order that units of proper capacity and number to insure economic and continuous service may be provided. Plants which are supplied by pumpage may be broadly divided into three classes, namely, those which distribute from a storage reservoir, from an equalizing reservoir, and direct from a station. Under the latter class those which are supplied with an equalizing standpipe should be included, for in only small towns can a standpipe furnish any reasonable proportion of the draft, and in the larger cities it is a useless adjunct, as the pressure can be as uniformly maintained by means of pressure governors.

The stations which deliver direct to the system will first be considered. Their pumping capacity should be sufficient to deliver the maximum domestic and fire draft combined, with any two units in reserve; and the boiler capacity should be sufficient to

enable the pumping of this maximum draft by the most uneconomical units in the station, with one boiler out of service for repairs or cleaning. This requirement of two reserve pumps over and above the maximum capacity has frequently been questioned, one of the foremost objections offered being the large amount invested for machinery which may never be called into use. The answer to this objection will be given along the line of cost. If the city were located in close proximity to a hill of sufficient elevation to furnish the desired pressure, the advisability of building a reservoir of sufficient capacity to assure the supply would not be questioned. Such a reservoir would cost, in round numbers, about $5 000 per million gallons, which corresponds closely with the cost of high-duty pumping machinery of equal capacity; and low-duty or centrifugal pumps can be purchased at a much lower figure. Viewed from the cost standpoint, therefore, no argument can be adduced against installing pumps to perform the same function as the reservoir.

Where an equalizing reservoir is in service, the pumping capacity need not be as great as in the preceding case, but there should be one unit in reserve over and above the maximum possible draft for ten hours, minus the reservoir capacity. When a station delivers to a storage reservoir, the pumping capacity should be equal to the average daily draft during the maximum month. Such capacities may perhaps appear high to many who have successfully maintained an ample supply from stations which are not equipped with the above-mentioned reserve units, but no station can be considered reliable unless it can maintain the supply at all times, and it is not infrequent in a station containing four or five units for two to be out of service at the same time, and, although one of the units may be undergoing only trivial repairs, such as replacing valves or packing glands, it would nevertheless be impossible to get it back in service on short notice.

The capacity for coal storage should be sufficient to hold fuel enough to run the plant through any period in which the delivery may be interrupted by strikes or unfavorable weather conditions, and coal to meet such emergencies should, of course, be kept always on hand.

If the water is delivered direct from the pumping station to the

distribution system or to an equalizing reservoir, there should be two or more discharge mains, and their capacity should be such that with any one main out of service, the other or others could deliver somewhat in excess of the maximum domestic consumption; and, of course, it would be much more desirable if, under such circumstances, the maximum domestic and fire draft combined could be provided for. When delivering into a storage reservoir, one main having a capacity equal to the maximum daily rate is ample, for repairs can be made before the water in the storage reservoir will be exhausted.

To-day filtration plants are in operation in many cities, and the capacity of these plants need not be as great as the maximum hourly rate of consumption if enough filtered water is held in storage at some point on the works to provide for the drafts. On many plants this supply is provided by large covered clear-water basins which supply the high-lift pumps. In some plants a bypass is installed so that unfiltered water can be delivered direct into the distribution system in case the fire draft exceeds the capacity of the filters and exhausts the supply in the clear-water basins. Where the original source is contaminated, however, this expedient should not be resorted to, but provision should rather be made for additional clear-water storage, as an epidemic is even more undesirable than a conflagration.

The supply mains connecting the storage or equalizing reservoir with the distribution system should be bypassed around the reservoir, and of such capacity that the maximum rate can be delivered with any one main out of service. In some cases, the installation of cross-connections and suitably located gates in the supply mains enables their size to be somewhat reduced. Blow-offs should be established at all low points, for it often requires more time to empty a main and dispose of the water than it does to accomplish the actual repair work.

In the construction of force and supply mains, the question of material is often difficult to settle. Cast iron, wrought iron, steel and wood are each used with good results. Up to thirty inches in diameter, cast iron generally proves the more economical, but in larger sizes steel lines prove cheaper even if they have to be replaced within twenty-five or thirty years. Besides, it is im-

practicable to use cast iron in mains of more than sixty inches in diameter. The carrying capacity of lines constructed of either material gradually decreases, but the cast-iron lines can be cleaned and their capacity restored at a nominal cost. On the other hand, cast iron is subject to rupture, which will put the line completely out of service, while in the case of steel any general weakening of the structure is portended by small leaks. Continuous wood stave pipe has proved very reliable; it is almost always cheaper, can be readily repaired, and maintains its carrying capacity throughout its life.

All force and supply mains should be equipped with air valves at their high points, and they should be frequently inspected, for a defective air valve will cause a steel or wood line to collapse in case of a break at one of the low points.

There is no better item to observe than the per capita consumption records if one cares to make a snap judgment in regard to the efficiency of the operation of a water-works system, for almost invariably the high consumption rate is a sign of inefficiency, and, conversely, the low consumption rate is indicative of efficiency. The per capita rate which is necessary to meet modern conditions in our cities ranges from about 50 to 150 gallons per day, but these rates are exceeded in most of them. This unnecessary consumption has a very important bearing upon the question of cost, for it has to be met by the development of larger supplies, the construction of additional filtration works (if there are any), and the installation of additional pumping equipment and of force, supply, and distributing mains of increased carrying capacity, if the domestic and fire-flow requirements are to be fully met. Unfortunately, in such instances the fire-flow is generally only partially provided for during periods of maximum domestic consumption.

The installation of meters is the surest and practically the only way to effect a permanent reduction of the per capita rate. Many and fallacious as are the arguments advanced by the opponents of the general installation of meters, the results where they have been installed are incontrovertible. Water-works engineers are not as yet agreed that the metering of all services is an economic necessity, but the results attained in cities that have metered

practically every service show that as much benefit may be derived from metering the last ten per cent. of services as was obtained from any prior installation of an equal number of the same size. The water used in public buildings and for other municipal purposes is generally far in excess of that actually needed. In cities which have paid particular attention to this class of consumption, the conclusion reached is that all water used by the several city departments, except for the extinguishment of fires, should be metered and paid for by the users. Such a course not only effects an important reduction in consumption, but gives the water department credit for the service rendered.

One of the points upon which insurance and water engineers differ is in regard to the metering of fire services. The water-works engineer, who generally takes the affirmative side of the question, is in much closer touch with the situation, and when such results as the following are obtained, there seems to be no doubt in regard to the justification of his stand.

Worcester, Mass., metered all fire services in 1905, and the following year the revenue increased $15 000, and the consumption decreased over 300 000 000 gal.

Lockwood, N. Y., metered all fire services, and the following year the revenue increased 25 per cent. and the pumpage decreased 20 per cent.

The pressures which are maintained on works which are supplied by gravity from distributing or equalizing reservoirs are governed by the elevation of the reservoirs. In many cases suitable sites are not available at desired elevations, but when they are, it is highly desirable to so locate the reservoir that a pressure of 100 lb. will be maintained over the greater portion of the distribution system, and particularly in the closely built-up sections. In a recent paper,* Mr. E. V. French dwelt upon the advisability of such a pressure, and showed that it was sufficient to furnish direct hydrant hose streams to all fires except those in the larger and higher buildings, for which more powerful streams would have to be furnished by fire engines. As the number of fire engines can be greatly reduced if many streams can be taken direct from the hydrants, a very considerable saving can be thus effected,

* Journal N. E. W. W. A., Vol. XXV, p. 247.

for it costs between three and four thousand dollars a year more to maintain an engine company (horse-drawn) than to maintain a hose company. In planning for extensive improvements in any city, therefore, it is desirable to provide, if possible, for the raising of the pressure to about 100 lb., for in addition to cutting down the expense of the fire department, other economies can in this way be also effected. Take, for example, the large cities of New York, Chicago, Philadelphia, and Buffalo: in these it is necessary to pump all the water used in buildings of moderate height and in small plants, and this could be done more economically in one central station. Of course it would still be necessary to pump the supply to buildings over 200 ft. in height, but these are comparatively few.

Next in importance to the saving which could be accomplished is the increased reliability of sprinkler equipments when supplied from a central station. The number of such equipments in service is increasing rapidly, and they constitute practically the only safeguard to buildings of non-fireproof construction and fireproof buildings containing combustible material. In many systems supplied by direct pumpage provision is made to raise the pressure upon receipt of fire alarms and maintain this pressure until the "all-out" is sounded. This practice is good, and may well be adopted in all such systems. The permanent raising of pressure on a system does not necessarily increase the consumption, for thorough inspection and the prompt following up of defects will enable an unincreased consumption rate to be maintained. This has been proven in several cities during the past few years, and though heavier materials, requiring more careful workmanship, are used in the original installation, the subsequent cost of maintenence of a distribution system under 100 lb. pressure is no greater than under 50 lb. pressure.

Few engineers have the opportunity to design a new distribution system for a city of any considerable size. New Orleans is the only large city which has installed a new piping system in the last score of years. The problem of to-day is the reinforcement and rehabilitation of outgrown distribution systems, or of systems which have deteriorated in carrying capacity or were faulty in their original design. To accomplish this task, a careful study

of the existing system should be made, present requirements determined, and proper allowance made for future growth. This done, a plan for all future work should be adopted and followed. This plan should include main arteries of ample carrying capacity girdling the city as its growth demands, secondary feeders of suitable size about 3 000 ft. apart in either direction, and dead-end lines extended to outlying sections without reduction in size, — the system to be so designed as to furnish fire protection as follows:

(*a*) In outlying residential districts not likely to become closely built up, a minimum of 1 500 gal. per minute.

(*b*) In closely built-up residential and minor mercantile sections, 2 000 to 5 000 gal. per minute.

(*c*) In manufacturing, warehouse, and congested value districts, from 5 000 to 20 000 gal. per minute, depending on the structural conditions.

The above supply should be in excess of the maximum daily domestic consumption, and should be available in manufacturing districts to any large group of buildings of special hazard, and in mercantile and residential districts about any block. In order that these quantities shall be available, the following minimum sizes of mains should be used for hydrant supply:

For residential districts, 6-in. and 8-in. mains, the former to be used only where they complete a good gridiron, and the latter in locations where dead-ends and a poor gridiron are likely to exist for some time, and in all blocks 600 ft. or more in length.

For mercantile and manufacturing districts, 8-in. and 12-in. mains, the former to be used only in sections where they complete a good gridiron, and the latter for long lines not cross-connected.

Four-inch mains cannot furnish sufficient hydrant supply, and should be replaced as fast as circumstances will permit, the replacement to commence in the more thickly built-up sections. In order that not more than one hydrant will be on a 6-in. nor more than two hydrants on an 8-in. main between intersecting lines, dead-ends should be eliminated wherever practicable, large mains cross-connected to distributors at all intersections, and long unsupported lines of pipe cross-connected.

The city of Reading, Pa., affords a good example of the results which may be accomplished by the adoption of a well-designed plan to be followed out in future construction. Some seventeen years ago such a plan, prepared by the superintendent, Mr. E. L. Nuebling, was approved by the city, and has been followed since that time. At present there are ample quantities of water available for both domestic and fire protection purposes throughout the entire system, and future additions to meet increased growth in population can be readily and economically made.

Unfortunately, the topography of some cities precludes the making of plans for future growth, for it is impossible to foresee in what direction that growth will extend. For a number of years the probable growth of Los Angeles appeared to be in an easterly direction, and it is only in the past two or three years that a definite trend showed it to be in a westerly and southerly direction.

Tar-coated cast-iron pipe is unquestionably the best material to install in a distribution system. In some parts of the country kalameined pipe is extensively used, because of the saving in freight rates which can be effected on account of its lighter weight, and this pipe gives very good results. Machine-banded wooden pipe does not give satisfaction in a distribution system on account of the excessive leakage which generally occurs. Cast-iron pipe should be inspected at the foundry and again before it is lowered into the ditch. Special care should be taken to prevent any foreign matter from getting into the line during laying, and the line should be thoroughly blown out before it is put into service. If practicable, a test pressure of one and a half times the working pressure should be applied to the line before backfilling.

Pipe less than 6 in. in diameter should never be installed to furnish hydrant supply. In cities where the distribution system is weak, it is desirable not to install any pipe less than 8 in. in diameter, for the new lines of these larger sizes will reinforce the old lines. The weight of pipe purchased should be sufficient to enable at least 300 ft. head to be maintained at the point of lowest elevation in the city. If the heavier classes of pipe are installed, it enables the pressure on the system to be raised to the desired point without the additional expense which would otherwise be required for relaying. The coefficient of carrying capacity of the

older lines should be determined by experiment, and in many cases, where the supply is deficient, the results obtained will show that it is more desirable to clean the line than to lay a new line. Sufficient cover should be provided to insure the pipe from freezing, even in the coldest winter. Exposed pipes at bridge crossings should be well supported and protected from injury, and extreme care should be paid to the design of the line near the approaches.

Electrolysis is a subject which must not be neglected, for it is most insidious in its action. Frequent surveys should be made, and remedial measures approved by the best water-works practice, rather than those generally advocated by street railroad engineers, should be adopted. Grounds from electric circuits should be made on the street side of the meters, main cocks, etc., in accordance with the National Electrical Code, and no power circuit which depends upon a grounded return should be connected to the system in any manner.

In order to operate a distribution system with the desired facility, the mains should be equipped with gate valves so located that no single case of accident, breakage, or repairs to the pipe system in important mercantile and manufacturing districts will necessitate the shutting from service a length of main greater than the side of a single block, or a maximum of 500 ft., or in other districts a length greater than two sides of a single block, or a maximum of 800 ft. If possible, the location of gates should be uniform; that is, they should be set on the property or curb lines at street intersections, so as to be more readily located. On paved streets it is advisable to provide a box or vault of sufficient size to permit of packing the gland without excavation. When the approximate location of a box is known, and it is covered by dirt on an unpaved street, or by ice, a pocket compass will prove an invaluable aid in determining its exact location, for by passing the compass over the supposed location, about an inch above the ground, the needle will deflect toward the iron cover, and by a little careful work can be made to indicate the exact center of the cover. The compass will determine the location of a box that is covered as deep as one foot. This method is also of use in finding cast-iron service boxes which have been covered by granolithic sidewalks.

The gate valves on a system should be inspected at least once a year, at which time they should be operated, and packed if necessary. The boxes should be kept clean, and if water is liable to collect and freeze in them, they should be provided with a drain to the sewer or be pumped out. All operating nuts should be of the same size, and all gates should operate in a uniform direction. On a system of any considerable size, gates should only be operated by employees specially assigned to the work, and a record should be kept by them of each operation. Careless inspection and operation is sure to cut down the carrying capacity of the system by allowing some gates to remain closed, and frequently causes serious delays in cases of accident. Occasionally division gates between different services are left open, and the apparent increase in consumption in the higher service is puzzling to the superintendent until the cause is discovered. In one city where a record of gate operation was not kept and inspections were infrequent, an examination of 7 000 valves showed:

49 closed and 300 partially closed valves on lines from 4 to 20 in. in diameter.

12 inoperative valves.

100 valves either not on the plans or not in the ground.

2 gate vaults completely filled with crushed stone.

1 division gate open.

1 952 boxes requiring cleaning.

In a smaller city an inspection of 40 valves showed:

1 valve closed.

1 valve with a broken spindle.

1 valve so deep that it could not be reached with the wrench.

2 valves operated in a direction opposite from the others, and no note made of the fact on the plans.

2 valves inaccurately located on the map.

3 valve boxes filled with bricks and earth.

1 operating nut too large for the wrench.

The hydrant is the last link in the chain from the source of supply to the point of delivery to the fire hose lines. Hydrants should have 6-in. barrels with 6-in. gated connections to the main and a foot valve having a free waterway of at least 20 sq. in., so that the loss when 1 000 gal. are being withdrawn shall not be

excessive. In cases where provision is made for more than one engine to take suction from a single hydrant, the above dimensions should be increased, and no loss greater than 4 lb. should be permitted when hydrant hose streams are utilized. The operating nuts of all hydrants in a system should be of uniform size and turn in the same direction. Where hydrants are supplied from different services it is advisable to paint those on separate services a distinctive color. Care should be taken to have the threads on the outlet nipples of the same size as that adopted by the fire department for hose couplings, and it is especially desirable to adopt the National Standard hose thread, so that apparatus summoned from neighboring cities can make connections.

Hydrants should be frequently inspected to assure their operation. They should be packed and lubricated, and the outlet caps greased, at least once a year, and they should then also be operated and blown out. Before cold weather sets in they should be carefully inspected for drainage, and if any are set below the ground-water level the drips on such should be plugged and the water in the barrel pumped out. During periods of cold weather those in high-value districts should be inspected once a day, and those in other sections twice a week. Special connections should be provided for filling flush wagons and sprinkling carts, and the use of fire hydrants should be confined solely to the fire department.

The question of the distribution of hydrants in a city is a very important one from the fire department standpoint, on account of the great friction loss in long lines of hose. The distribution should be such that ample quantities of water can be delivered to a large fire from hydrants at an average distance therefrom of not more than 350 ft. The customary method of figuring hydrant spacing on a linear basis does not convey any definite information, for, without a knowledge of the size of the blocks, linear spacing would be apt to convey an erroneous impression. For example, the locating of hydrants at linear distances of 200 ft. in one city where the blocks are 200 ft. square would, in the matter of distribution, be equivalent to the locating of hydrants at linear distances of 100 ft. in another city where the blocks are 800 ft. square — in either case the area served by a single hydrant being 40 000 sq. ft. Under the differing block conditions referred to,

Portland, Ore., illustrative of the former, would require one hydrant at each street intersection, or one hydrant to a block; while Salt Lake City, illustrative of the latter, would require 16 hydrants to each block between the center lines of the four bounding streets. It is clear, therefore, that the area in square feet served by each hydrant is the proper unit to adopt in order to be able to determine the adequacy of hydrant distribution and to make comparisons. Where it is necessary to concentrate 10 000 or more gallons of water per minute upon any building or block, there should be one hydrant for each 40 000 sq. ft. In minor mercantile and small manufacturing districts and in densely built-up frame areas, there should be one hydrant for every 60 000 sq. ft., and as the buildings become less congested the distribution may become wider, up to 120 000 sq. ft. in outlying residential sections.

From the operating standpoint the inside independently-gated hose outlet cannot be considered as giving the best results. The leverage furnished by the wrench ordinarily used by the fireman is far in excess of that required to operate a valve of equal size in any other service, and so great that the stem can be broken or other parts crushed without any undue exertion on the part of the operator. The end to be attained may best be accomplished by attaching outside hose gates before the hydrant is open, and such a procedure will not introduce an objectionable delay. Such gates carried on hose wagons are more reliable, as they can be easily inspected and kept in working order.

The matter of original expense is also a very important item. Assume a city with 2 000 hydrants and 16 hose or engine companies. To equip the $2\frac{1}{2}$-in. outlets on all the hydrants would cost over \$20 000, while to supply the 16 companies, each with four hose outlet valves, would cost about \$650, and the cost of maintenance would be in about the same proportion. It is not so practicable to deal with the $4\frac{1}{2}$-in. steamer outlets in the same way, because the portable valve is much heavier, so where it is desirable to connect a steamer to a hydrant which may already be delivering to a hose line, or where there are two steamer connections on a hydrant, it proves more convenient to equip these outlets with inside gates.

The purchaser of a hydrant should insist upon having the waterways carefully designed, the castings smooth, and the workmanship good. The neglect of these points often admits of the installation of a type of hydrant which is well-nigh valueless. There are hydrants in service in some cities to-day which show a loss of 35 lb. between the street main and the hose outlet when 600 gal. of water are being drawn, whereas there are many hydrants of reliable make and at reasonable cost which can deliver the same quantity of water with a loss of less than 4 lb.

The requirements necessitated by the fire protection problem are, of course, a large factor in the cost of a water-works system, increasing that cost from 50 to 100 per cent. over what it would be were the question one solely of furnishing water for domestic and business purposes. But these requirements have to be met, and while in no one city are they all fully provided for, a large number of our municipalities are earnestly endeavoring to attain the best possible results in this connection, and it is to be hoped that their example will be speedily followed by those that now lag behind in the matter of water-works administration.

It is evident from the foregoing that the fire protection problem is one of the first importance for the water-works engineer, for it is primarily with him and the fire department that its solution lies. It is perhaps not to be expected that any water-works system will fully meet its requirements in all their complexity of detail, but while the ideal is never attainable, it is always more and more nearly approachable. That it may be the more nearly approximated to in the design, construction, and maintenance of a water-works system, our municipalities should make it an indispensable part of their policy to secure for this work the best engineering talent available, and then leave it unhampered by political or other considerations to pursue its course toward the realization of what men are striving for and municipalities hoping for, — the watchword of the century, — a maximum of efficiency at a minimum of cost.

DISCUSSION.

Mr. Frank L. Fuller.* Mr. President, I think the author has set a high standard for water-works construction, and while there are details as to which engineers and water-works men would differ, still it seems to me that on the whole he has given us an admirable lay-out. He deals, perhaps, more particularly with systems for cities and large towns, while works that are being built at the present time are generally for smaller towns, and the requirements for them, therefore, would probably not be equal to those represented in this paper.

Mr. W. C. Hawley.† Mr. President, this excellent paper has covered the ground thoroughly, and every practical water-works man will agree to a very large extent with the opinions which have been expressed. It brings us to the question of the cost of all of these things which enter into the construction of a well-designed and well-built water-works system and *who is going to pay for them,* and that, I believe, is one of the matters that we have got to study into, and about which we must educate the public. Those of us who are connected with privately owned plants are confronted with this problem constantly. A neighboring municipal plant is selling water at a low rate per 1 000 gal. and is not charging for fire protection. Nothing is said as to how much is being raised in the municipality by direct taxation on account of the municipal water department or the quality of service or that probably no depreciation is being earned, and the result is that the comparison of rates between the municipally owned plant and the privately owned plant is most unfair, and yet a large part of the community supplied by the latter is firm in its belief that the grasping private monopoly is robbing the people because its rates are higher than those charged in the municipality.

The investment in water-works plants for furnishing fire protection may vary from 80 per cent. of the total cost of the plant in the case of a small water works down to a very small percentage of the total cost in the case of a large one. It is not fair that the expense of furnishing fire protection should be met by the domestic

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or the industrial rates, but it should be met in the case of the municipal plant by direct taxation, and the people should know what they are paying for and what it costs. In the case of privately owned plants a charge to the municipality must be made for fire protection, to be raised by taxation, or else the cost of furnishing fire protection must be added to domestic and industrial rates. Few, if any, water companies are charging what it is actually costing them to furnish fire protection, to say nothing of a reasonable profit upon the business. The computation of the cost of furnishing fire protection is a matter requiring skill and judgment, and cannot, of course, be made with great accuracy. In its calculation, however, so far as I know, every question involved has been solved by giving the benefit of the doubt to the fire protection; and even when a minimum cost has been computed, few, if any, water companies have named rates which would return the cost of the service. In some cases it has been customary to purposely add a part of this cost to domestic rates, and this has been justified on the ground that fire protection is received on both buildings and contents and that in many cases the contents do not belong to the owner of the building but to the occupant, who is either directly or indirectly the one who pays the domestic rates, and in this way he bears a share, at least, of the cost of furnishing fire protection.

Rate-making in the past has been to a large extent a matter of guesswork, but with the introduction of public utility commissions throughout the country, rate-making will be put on a more scientific basis. Sooner or later, we are all going to be confronted with this problem, and we shall have taken a long step in advance when the public comes to know something about the investment necessary to furnish fire protection and what it costs, and meets it by direct taxation instead of by some species of indirect taxation as at the present time.

SOME DIFFICULTIES ENCOUNTERED IN TUNNEL AND SUBWAY CONSTRUCTION IN BOSTON.

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[*Read November 13, 1912.*]

This paper is divided into several parts, the first relating to the pipe changes in connection with the various subways built to date in this city; the other parts describe two compressed air tunnels; the building of the Deer Island Reservoir, and some other work on which the author has been employed.

TREMONT STREET SUBWAY.

When the first subway was built in 1895 — about 1 200 ft. of Tremont Street was taken for its location. The City had had since 1847 along this line two 30-in. pipes laid about 5 ft. apart on centers, and the subway roof came either just up to or just above the level of both these pipes. It was proposed at that time to relay them entirely away from and around the subway so as to avoid all difficulty of caring for them during construction, and later events have rather proved the wisdom of such a course. It was, however, not adopted, and it therefore devolved on the water department to maintain these pipes by shifting, raising, or lowering them as was necessary for the construction of the subway, all with the coöperation and assistance of those in charge of building it.

The subway was constructed by the "cut-and-cover" system; that is, alternate sections of about 20 ft. were opened at the same time and work carried on under cover of planks at the street surface. Work was never stopped, either at night, on Sunday, or on a holiday. The city maintained but one inspector on the work all the time, with three shifts. The conditions found after several breaks had occurred demonstrate and emphasize the importance

of the thorough inspection of work involving the foundations for heavy pipes.

There were at the same time perhaps twenty of these 20-ft. sections being worked on, in various stages of construction. The instruction given to every one concerned was to allow no rigid material to be set nearer to the bottom of the pipe than 4 in., that is, the pipes, as the old foundations were undermined, were set on 4 in. of blocking, and the subway roof was carved out under the bells where necessary to allow 4 in. of earth between the

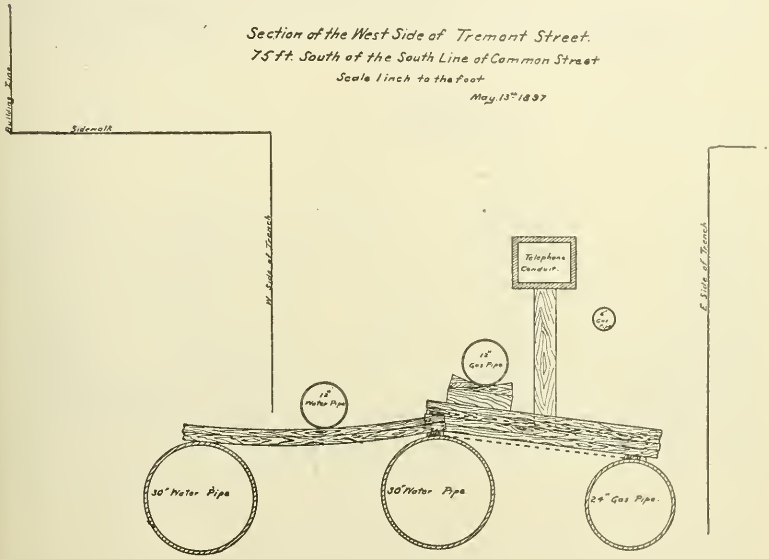

FIG. 8.

pipe and any rigid material underneath. These orders, if faithfully carried out, would have prevented large financial loss and annoyance from breakage, although to have carried them out would have required at least four times as many inspectors as were employed, and it was not at that time realized that such plain directions as were given would be so disregarded. There have been, so far, eight breaks of either one or the other of these pipes over the subway, costing for repairs about $9 000, and over

$50 000 more for damages. In every case where a pipe broke, it was at a point where it could settle, in close proximity to a rigid bearing where it was so firmly held that it could not yield, and under the enormous leverage the pipe cracked invariably along the center line of the bottom. Figs. 8 and 9 show sections of the pipes as found after the breaks.

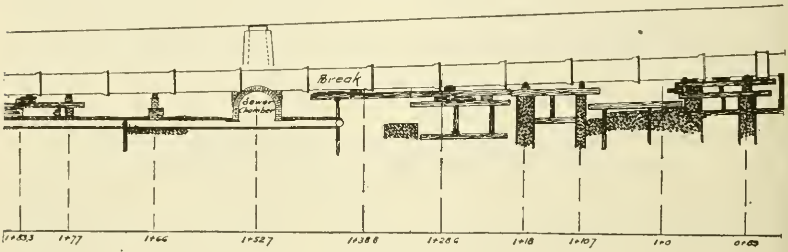

FIG. 9.
SHOWING SUPPORTS FOUND UNDER PIPES.

The two 30-in. mains before referred to had to cross the subway at a point on the Common, and, on account of the head room over the subway being so slight, these pipes had to pass under it. This was done by means of a sub-subway about 40 ft. below the surface of the Common, the pipes at this point being 30- and 40-in. respectively. The old pipes were maintained in service until the new ones were turned on, the work being done at night, on Sunday, and on a convenient holiday. The angle made by the pipes with the crossing was so acute as to make the length considerably longer than the width of the subway.

It is the policy of the water department to use as few single-casting quarter-bends as possible, especially in the larger sizes, so that two one-eighth bends had to be used wherever a 90-degree curve was necessary. As has been found many times, and probably referred to in past meetings of this Association, two eighth-bends rarely fit so as to make one quarter-bend, due probably to improper allowance made for shrinkage at the foundry. It was after considerable trouble, therefore, that these bends were finally fitted and anchored in place. The manner of anchoring is shown in Fig. 10.

Reinforcing rods were so set as to hold the masonry in place against a considerable head in case any leak should develop in the pipes, the water appearing first at a manhole on the surface of the Common. The shafts are filled around the pipes solidly with concrete, the curves in addition being anchored in place. This work was designed by the Transit Commission.

During the construction of the subway one of the 30-in. mains was moved laterally about 5 ft. and at the same time lowered 18 in.

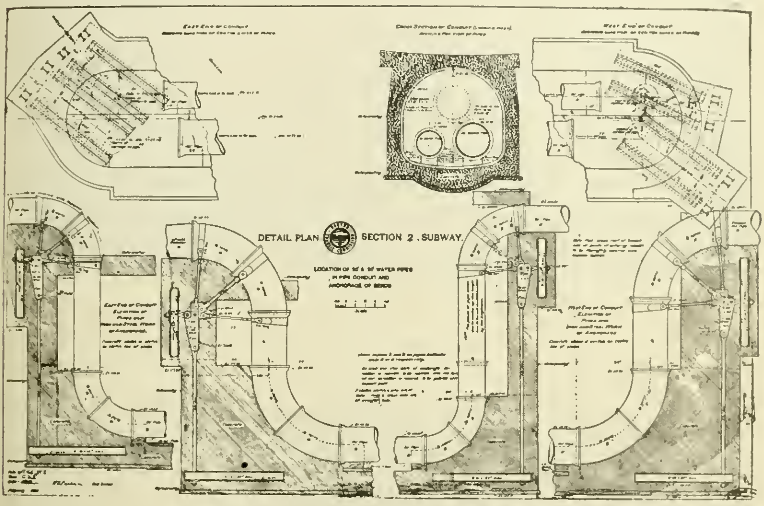

Fig. 10.
The 30-inch Pipe crossing under the Subway, showing the Method of Anchoring.

This was accomplished at one operation. The pairs of timbers between which the lifting screws were operated were set on an incline on rollers, the lateral movement being made by barring, the pipe then dropping by its own weight as the screws were simultaneously loosened. Plate XII, Fig. 1, shows the method of shifting this pipe.

THIRTY-INCH STEEL PIPE.

When the second subway, or tunnel, so-called, was built under Washington Street, it was decided to avoid all possible future

trouble, at least over the subway, by laying about a mile of 36- and 24-in. pipe around and well away from the site of the work. This was done by the regular force of city laborers, chiefly on account of the supposed difficulty of doing this kind of work by contract in crowded city streets. This is the first case of a pipe of this size laid through the extremely congested streets of Boston. It was slow and expensive work, and many corporations felt that their vested or acquired rights in the streets were being ignored, and although every attempt was made to avoid the disturbance of other structures wherever possible, many of them were compelled to give way as the main was laid. Where the Washington Street tunnel was crossed, two right-angle turns were made, about 25 ft. apart.

As it was an exceptionally poor place to anchor curves, and as the tunnel was planned so near the street surface as to render it impossible to lay the proper size of pipe, it was decided to lay a short piece of 30-in. flanged-steel pipe, including the two bends. This insertion has so far given no trouble.

At the time the subway was built in the Common, the City desired to lay a 24-in. high-service main across the proposed subway at West Street. As was often the case, there was no room for that size of pipe over the subway, so three bays were left in special construction, and three 16-in. pipes were laid instead.

CASTLE SQUARE.

When the South Station was built, the old roadbed of the Boston & Albany Railroad was doubled in width as far out as Back Bay Station, involving the lengthening of all the bridges. At Castle Square the City had two 30-in. pipes crossing by an overhead bridge. The widening was so planned as to permit a street to be used directly over the new roadbed. This made the thickness of the street at this point too little to permit of a larger size pipe than 20 in., so four 20-in. pipes were laid in place of the two 30-in., wye branches being used at each end. Some fear was felt that a long line so little protected might freeze, and as at that time a patented covering, composed of felt, resin, and tallow, was coming into use, one inch of this was put around these pipes. Under these pipes, to protect them from the blast of the locomotives,

Fig. 1.
The Method used in Shifting 30-in. Pipe.

Fig. 2.
Piping at Castle Square.

cement mortar was thrown, below this being a plastered wire netting. Over the bays was placed a steel plate, on which rested the roadbed composed of asphalt $1\frac{1}{2}$ in. thick.

For some years observations of temperature were made at this point, but the water in the pipes never reached the freezing point. Plate XII, Fig. 2, shows the work at Castle Square about half completed.

COMPRESSED AIR TUNNELS.

The earlier pipe crossings of the harbor were made by siphons where the pipe was embedded in concrete enclosed in a heavy wooden box, and the entire siphon sunk in one piece. As changes occurred in depth or width of the channels, it appeared wiser to make these crossings safe and beyond the reach of any future disturbance. Accordingly three crossings were made in 1904 and 1905, of which two, the one at Dover Street and the one at Mystic Wharf, were in charge of the writer. As all were done under similar conditions, a description of one fits all.

The longest of the three tunnels was at Mystic Wharf, where the distance between the shafts was about 550 ft. The shafts were 60 ft. in depth. In every case a wrought-iron cylinder was sunk over the shaft location, and weighted so that it would sink well into the mud before the air was put on. The cylinder was then lined with the brick as designed, causing still further settlement. The small air lock was then put on and on the application of the air, the water lowered in the cylinder. The process of operation from this time was to excavate from 4 to 6 ft. beneath the lower flange and for 1 ft. out from the inner edge of the cylinder, and then to lay brick in its permanent position in the shaft, the cylinder being supported by its own friction. A circular row of pipes had been driven around the shaft to guide and hold it in position.

Speed is always slow on this part of the work, on account of the restricted space in which to lay brick. The shafts were 8 ft. internal diameter, the excavation was almost wholly in stiff blue clay, with some sand seams. The lines were maintained from a base line 4 ft. long, from holes bored in the bottom plate of the air-lock, piano wire being used with plumbs in water at the base of the shaft. This line was produced, and operations repeated again

and again, and from this short base line, no appreciable error was found when the second shaft was opened 550 ft. away. Plate XIII shows the general plan of one of the tunnels.

The mode of procedure in tunneling was as follows: A length of 10 ft. of the upper half of the tunnel was excavated, the material being carved out easily, and the roof was then held in place by curved flanged plates supported by posts, the plates being bolted and left in place, forming the backing for the brick. The lower half of the tunnel was then removed and the bricks laid in the entire section. The men worked in 11-hour shifts throughout the work, and a speed of 5 ft. of finished tunnel per day was made. Occasionally 10 to 12 ft. would be excavated in one day. The brick lining was 1 ft. in thickness. A specially fine sand was used for the purpose of reducing leakage into the tunnel. After some months, however, all the tunnels were found filled with water. The inside of the tunnel was plastered with neat cement, no waterproofing material being used. The distance between the top of the tunnel and the bottom of the channel was 17 ft. The air-pressure varied from 18 to 24 lb., but one compressor being in service, excepting for a short time toward the end of the work. One tunnel carries a 16- and a 24-in. pipe, the other a 30-in. pipe.

It is believed that the greater safety of the pipes, the ease of making repairs, and the fact of the pipes being beyond the reach of any probable change in the channel more than compensate for the increased cost of this method over the older method referred to previously. Plate XIV, Fig. 1, shows the method of construction in tunnel.

DEER ISLAND.

Deer Island is near the mainland on the north side of Boston, and is used by the City for its penal population. The original pipes across Shirley Gut were two 8-in., laid so near together that if one broke the other was also liable to go. These were laid in 1871.

In 1896 an 8-in. pipe was laid across Shirley Gut, followed four years later by a 12-in., laid some distance away. The two types of flexible joint used in this vicinity are shown in Figs. 11 and 12. Fig. 11 design shows the style of joint in the old pipes; it resembles the old Ward flexible joint, in that the score is cut into the spigot,

PLATE XIII.
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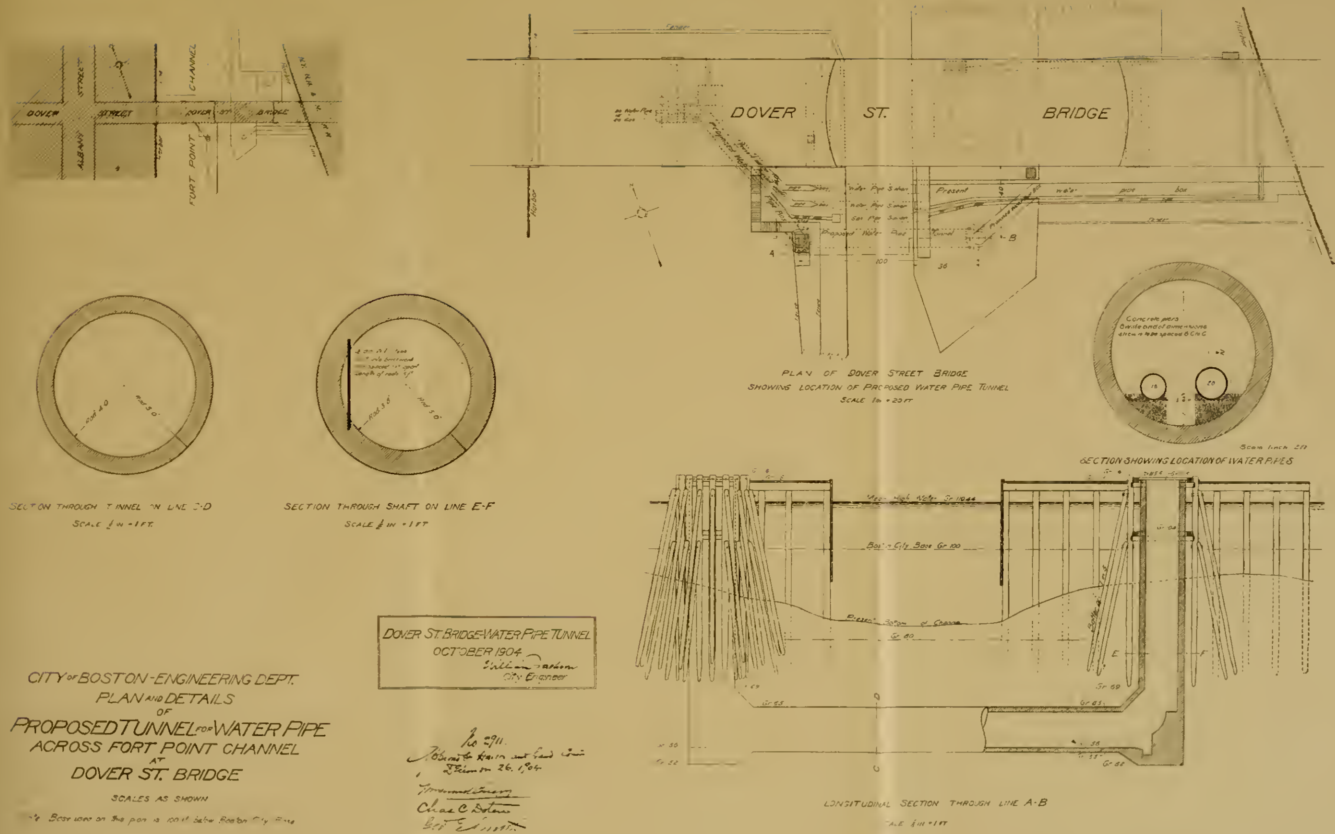
WINSLOW ON
DIFFICULTIES MET IN
SUBWAY CONSTRUCTION.



so that whenever a change occurs in the relation of two adjacent pipes the lead emerges from within the bell. The objection to this form of joint is that when the two pipes reassume their original position, the lead is liable to be skived off. In Fig. 12 design, which has been in use in the vicinity of Boston since 1895, the lead is held within the bell and does not emerge when the pipe shifts

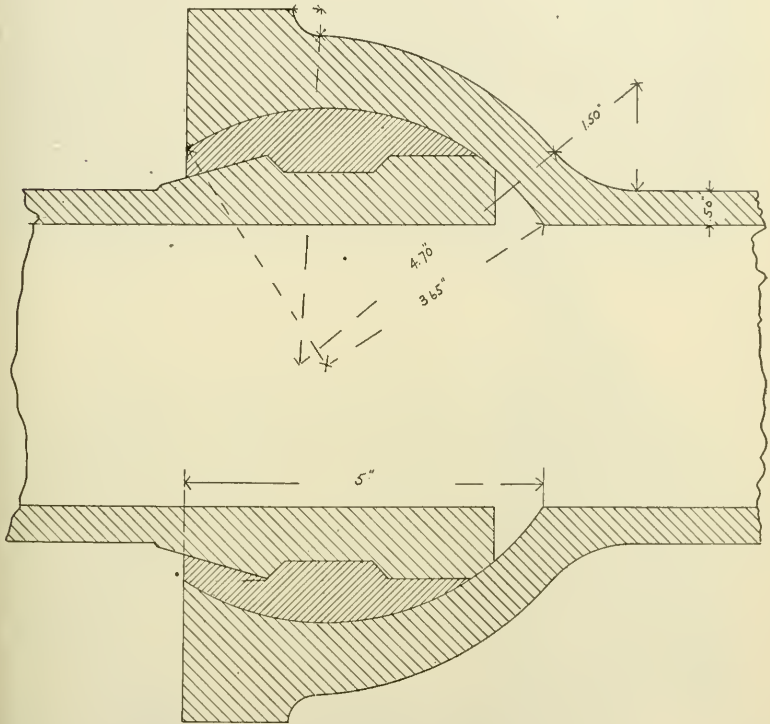


Fig. 11.
Flexible Joint with Lead on Spigot.

position. In laying, the pipe was placed on rollers in a long runway on the bank, and as the distance across Shirley Gut was but about 500 ft. it was easily pulled across by a capstan arranged on the opposite shore.

After these pipes were laid it was decided as a further safeguard

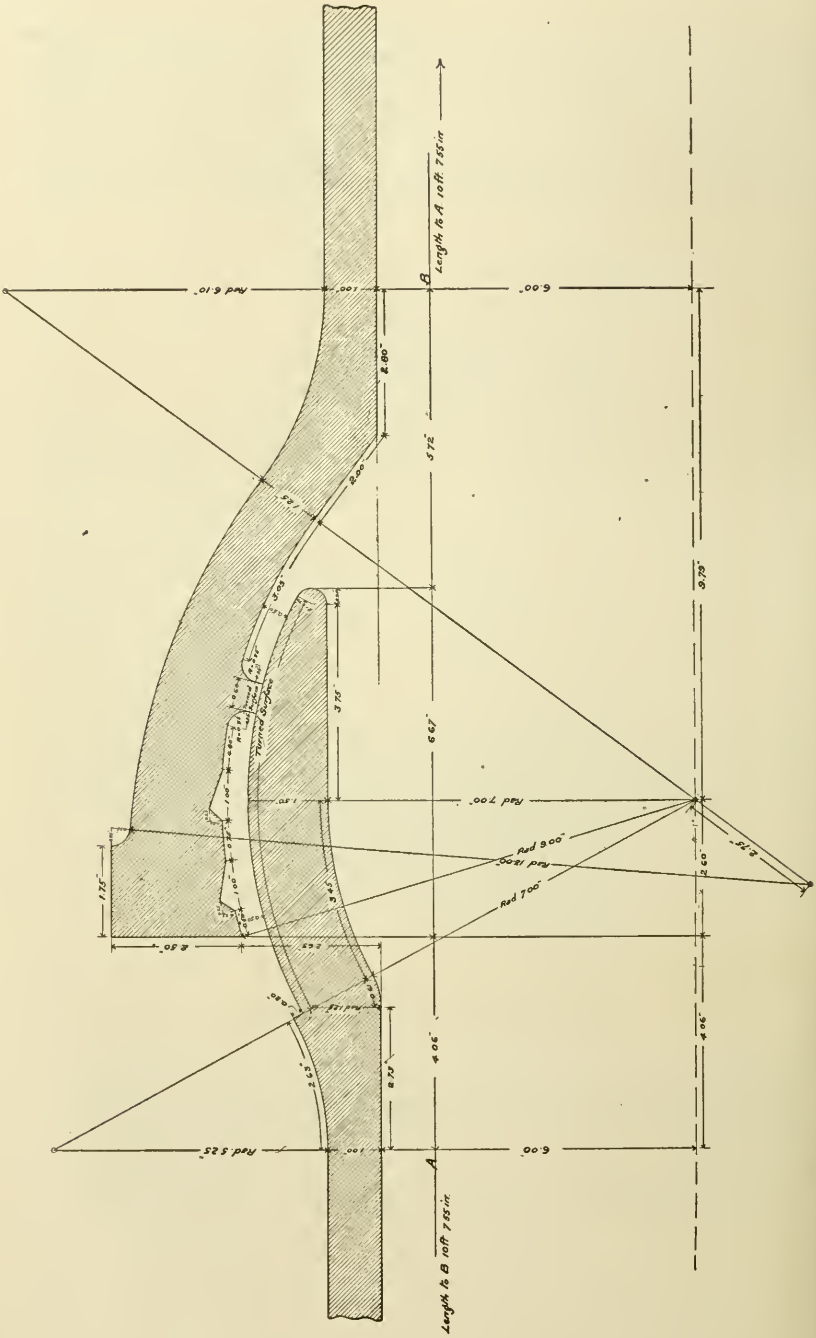


FIG. 12. FLEXIBLE JOINT WITH LEAD IN BELL.

FIG. 1.
TUNNEL CONSTRUCTION.

FIG. 2.
METHOD OF LAYING PIPE TO SPECTACLE ISLAND.

to the 1 000 to 1 800 involuntary inhabitants of the island to build a reservoir large enough to hold some weeks' supply and at an elevation sufficient to feed the highest buildings. The size settled on was of two and one-half million gallons capacity, the dimensions being 138 ft. by 43 ft. on the bottom, 231 ft. by 136 ft. at the water line, and 282 ft. by187 ft. at the extreme outside path. The reservoir was so designed as to equalize the cut and fill, but was slightly sunk to avoid too high a bank, as the Government proposed to have a station near by on the island for heavy gun practice.

The material of this hill, like all the drumlins in the vicinity of Boston, is an almost impervious hardpan, and rain falling on it would remain until evaporated. The peculiar features about this reservoir were the long time required in building it, and the low cost of the the labor involved. It took six years in building, all labor except a few foremen being taken from the ranks of those who were serving their county by working with no compensation save bed and board, or, in other words, " doing time " at a city seaside resort. They therefore had no particular incentive to labor, or to turn out specially good work, although they did do so.

The hours of labor were not lengthy, three and one-half hours in the forenoon, and two and one-half or three in the afternoon. There was no opportunity on this work to actually compare the labor with high-priced or free labor on similar work. Some years ago, however, the writer did compare the two kinds of labor in laying a mile or two of pipe, and found that the efficiency of the unpaid labor was from one eighth to one tenth of the paid labor.

High-water mark of the reservoir was elevation 109 ft. above City Base, the top of the bank being at elevation 114 and the bottom of the reservoir at elevation 88. The inside slopes were 2 to 1, the outside slopes being $2\frac{1}{2}$ to 1. All work in excavation was carefully trimmed to 6 in. below grade, and filled to grade with concrete of 1 : 2 : 4 mixture, the finished surface being plastered so as to present a smooth appearance. A flight of steps was constructed in order that sediment may be carried out from the bottom. No drainage pipe was provided, in order to save expense; in fact, all expense for materials was cut as much as possible.

The site was first stripped of the thin layer of loam found on the

island and the banks were built up in layers of less than 6 in. in thickness, and very thoroughly rolled when wet with a grooved roller, all large stones being removed. Up to the present time the reservoir has been filled and emptied several times, and there has never appeared to be any leakage or head behind the concrete lining, and no leakage has shown through the bank.

The overflow consists of a 16-in. pipe laid on a large block of concrete going well down into the concrete beneath the stone chips. The one pipe serving as intake and outflow is a 12-in. This was laid from the bottom of the reservoir to the gate chamber in tunnel. This tunnel was braced, in order to avoid any possible suits for damages, although it would undoubtedly have stood alone. To prevent leakage through this tunnel, it was back-filled with lean concrete.

The flow into the reservoir had to be controlled to prevent overflowing, so that the method shown of three 2-in. inlet pipes controlled by 2-in. ball cocks with 12-in. floats was adopted.

In the ordinary operation of the reservoir the check valve in the bottom of the chamber is shut by the pressure against it, water rises to the tank and flows down beyond the check valve into the reservoir. If the head in the pipes on the island drops, the reservoir acts automatically and the check valve opens. There are of course check valves on the island side of the two mains across the gut, so that if the pipes break, the reservoir would not be emptied.

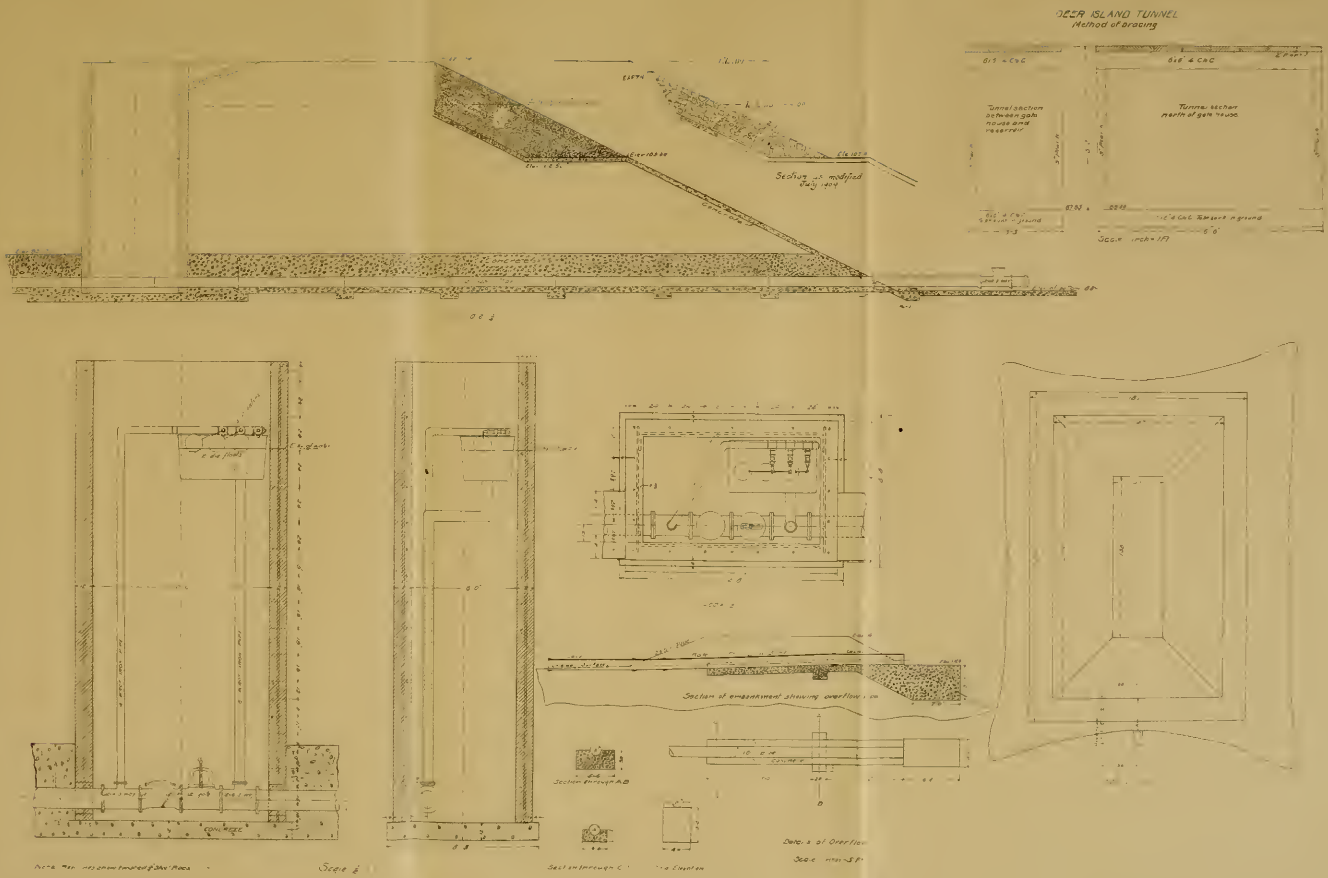
The material for the reservoir cost as follows: Cement, \$3 082; paving blocks, \$946; valves, \$218; lumber, \$474; a total of \$4 720 for material, or \$3 774 not including the paving blocks, which were purchased and used merely to give the slope a neater appearance. This reservoir is an example of low-priced construction where labor cost nothing and time is of minor consideration.

Plate XV shows the plans of the reservoir.

THIRTY-INCH CEMENT-LINED PIPE.

In 1900, it became necessary to remove and relay with cast-iron pipe about 850 ft. of the 30-in. cement-lined wrought-iron pipe which was laid into Charlestown in 1870. The reason for relaying was in no way caused by a failure in the old pipe, part of which is

PLATE XV
N. E. W. W. ASSOCIATION,
VOL. XXVI.
WINSLOW ON
DIFFICULTIES MET IN
SUBWAY CONSTRUCTION



THE DEER ISLAND RESERVOIR.

still in use and which, when laid in unyielding soil, has given good satisfaction. In constructing this pipe three 3-ft. lengths were joined in the shop. Over both of the riveted joints a clamp sleeve of proper curve section was placed, the space between the sleeve and the outside surface of the main being filled with neat cement. These 9-ft. lengths were joined together in the trench by a close-fitting sleeve 8 in. wide. The outside of the pipe was covered with 2 in. and the interior was lined with $1\frac{1}{4}$ in. of cement. The

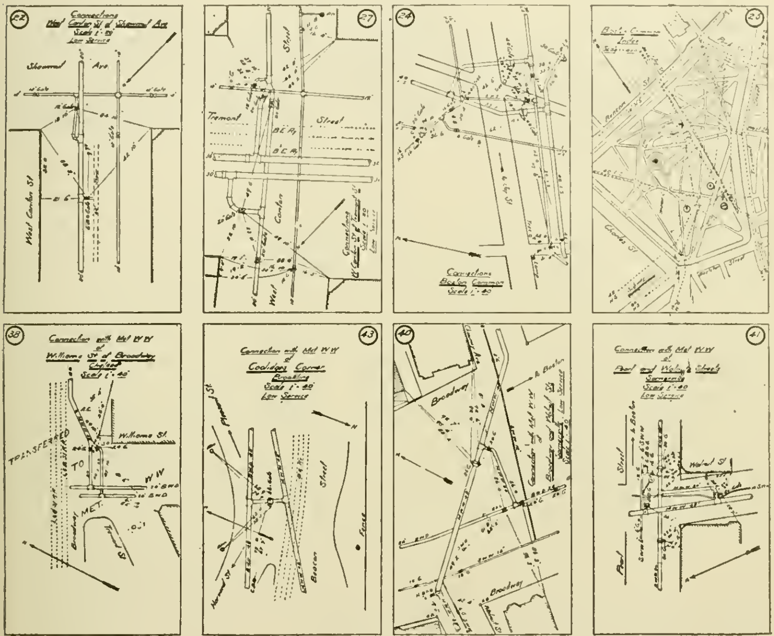


Fig. 13.
Valve Location Book.

wrought-iron composing the pipe was 0.16 in. thick, and in spots had rusted to 0.11. The cement removed seemed extremely inert.

PIPE TO SPECTACLE ISLAND.

During the present year a line of 4 000 ft. of 4-in. pipe, with Ward flexible joints, was laid connecting Long and Spectacle

islands. The 12-ft. lengths weighed 330 lb., requiring 18 lb. of lead per joint. A cradle 115 ft. long, resting on the bottom of the harbor, was used, in which to lay the pipe, the water being 28 ft. in depth a portion of the way. Plate XIV, Fig. 2, shows the manner of laying the pipe from the scow.

Fig. 13 shows a few sheets of a book of eighty or more pages, giving locations to gates on important lines for the use of those who are compelled to find them at any time.

As some portions of the matters referred to in this paper have previously appeared in *Engineering News*, the author desires to thank them for courtesies extended in permitting the use of the same. The author is also under obligation to the Boston Transit Commission, and to Mr. Edwin C. Hayden for photographs loaned.

USES AND ABUSES OF WATER FILTRATION.

BY GILBERT H. PRATT, CHEMIST OF THE RHODE ISLAND STATE BOARD OF HEALTH.

[*Read December 11, 1912.*]

In connection with the uses of filtration of water, the author would first mention a few of the conditions which call for such treatment. For many years a town or city may have been using some water of comparatively good appearance as a supply when suddenly there appears an unusual amount of typhoid fever among the people. Investigation demonstrates that it is the water supply which is common to these cases, and bacteriological tests prove that the water of the stream is polluted. Further investigation shows that there have been some cases of typhoid in a small village upstream, which has no sewage purification, and the excreta from these cases has found its way into the water supply of the downstream neighbor. This experience — such a common one in the case of cities and towns taking their supplies from streams which have an increasing population on the watershed — leads to a full appreciation of the need of purification, and the resulting improvement in the supply with attendant betterment of the health of the community serve as evidence of one use to which filtration is put.

Another city may be enjoyin , an exceptionally good health record, especially as to typhoid fever, but the presence of a large amount of organic matter, giving the water a high color and a vegetable taste, causes criticism of the supply, and, regardless of analyses as to its sanitary purity, a large number of citizens persist in the contention that the supply is not what an up-to-date city should be furnishing, until finally it is decided to filter the water by mechanical filtration in order to get a water of better appearance. The criticism above referred to immediately ceases, and the people receive a practically colorless water with comparatively no taste in place of the old familiar "organic brew."

Thus esthetic reasons may in many cases be sufficient cause for filtration, and the resulting output certainly justifies its use in these cases.

Similar to the above instance, the presence of different algæ may be the cause of disagreeable odors and tastes which demand filtration by methods which in such cases usually require aëration in conjunction with either double slow sand filtration or mechanical filters.

Some cities or towns and numerous small private supplies have been troubled, in cases where the supply is from driven wells, by the presence of iron in the water. This iron often exists in the lower state of oxidation or ferrous condition and upon contact with the air separates from the water as a " brick dust " sediment. Such supplies as this can be purified by methods involving aëration and oxidation of the iron before filtration or in the case of smaller supplies this has been successfully done by the use of a patented double filter which utilizes sand and animal charcoal.

Many industrial processes, especially bleaching and dyeing, require water of good color, low in iron, and free from turbidity. This requirement has resulted in the installation of a large number of filter plants, and the use of filtration for these purposes has been invaluable to numerous mills of this and other countries.

A great many times filtration is resorted to largely, if not entirely, to remove turbidity from the water. This is true of many western waters.

Having thus brought out different conditions which call for the use of filtration, the author will now cite certain concrete instances of installations which have been made for the different reasons above mentioned, and will present results which will show the efficiency of such plants when properly operated in improving the objectionable features which they were primarily installed to remove.

As instances of purification of supplies which have at times, prior to the use of filtration, been the cause of typhoid fever, — or, in other words, as instances to illustrate filtration for removal of bacterial pollution, — we may cite Lawrence, Mass., and Providence, R. I. The Merrimac River receives sewage pollution at Lowell and at many other points above Lawrence, and its

average bacteriological condition during 1910, to cite one typical year,* as received on to the filters, was a total count of 9 100 bacteria per c.c., and the colon bacillus, which is taken as evidence of the presence of sewage contamination, was present in all the samples examined in 1 c.c. tests. The output from the plant (old filter) showed only 57 bacteria per c.c. and the test for B. coli communis was positive in only 8.3 per cent. of the samples examined in 1 c.c. tests. This shows a removal of 99.4 per cent. of the bacteria and a very marked improvement of the conditions as to the presence of B. coli communis.

The water supply of Providence is obtained from the Pawtuxet River, and prior to the year 1906 was used without filtration. During these years there were at least two typhoid-fever epidemics which were traceable directly to contamination of the drinking supply of the city. The first was in 1882 and the second in 1888, the latter epidemic being caused by the fact that the attendants upon a case of typhoid fever had considered the river a means of quick disposal of the fecal matter of the patient.

Agitation for purification immediately followed this last epidemic, but it was a number of years before the type of filter could be settled; but finally, in 1902, the contract was let for slow sand filters, and beginning with 1906 the city was furnished with filtered water. The results were noted at once, not so much from the standpoint of color, — for as is the case with this type of filtration only a comparatively small per cent. of color is removed, — but by the freedom of the water from turbidity and sediment and by a reduction in the organic matter which had caused a marked vegetable odor and taste. Beside the visible improvement in the supply, the analytical study of the conditions before and after filtration showed the changes which were effected, and the excellent sanitary condition of the supply.

As an indication of the work which these filters have performed, I would present (Table 1) the following figures showing the average condition of the river as to appearance, color, and bacteria for four years from 1902 to 1905 inclusive as shown by bi-monthly tests made by the Rhode Island State Board of Health, and for comparison similar figures on samples taken from a tap in the city

* Massachusetts State Board of Health Report 1910, page 273.

covering the same period. These figures show that during this period the distribution system and reservoir storage effected some purification as shown by the slight improvement in the appearance, a removal of 10.9 per cent. of color and 81.8 per cent. of bacteria. Tests for B. coli communis were not made by the Board at this time.

TABLE 1.

PROVIDENCE WATER SUPPLY.

(1902—1905.)

Source.	No. of Samples.	Average Turbidity.	Average Sediment.	Average Color.	Average Bacteria per c.c.	Remarks.
Intake.	96	Slight to decided.	Considerable.	46	4,000	
Tap in city.	96	Very slight to slight.	Slight.	41	730	After reservoir system and distribution.
Per cent. removal.	—	Appreciable.	Appreciable.	10.9	81.8	

(1906—1911.)

Source.	No. of Samples.	Average Turbidity.	Average Sediment.	Average Color.	Average Bacteria per c.c.	B. Coli in 10 c.c. tested. Per Cent. of Samples.	Remarks.
Intake.	144	Slight.	Slight to considerable.	48	2,525	92	
Tap in city.	144	None.	None to very slight.	28	60	1.7	After filtration, reservoir system and distribution.
Per cent. removal.	—	Complete.	Almost complete.	41.7	97.5	—	

Similar figures are also presented (Table 1) showing the average condition of the river for six years subsequent to the use of filtration covering the years 1906 through 1911, and similar figures from a tap in the city for comparison. These figures show a

marked improvement in the appearance of the water, a 41.7 per cent. of removal of color, as compared with only 10.9 per cent. due to the reservoir system prior to filtration, which would indicate 30.8 per cent. due to the filters themselves, and show a removal of 97.5 per cent. of the total number of bacteria present. B. coli communis was found to be present in 92.0 per cent. of the number of samples tested on the river, and in only 1.7 per cent. of those taken in the city during the filtration period, these tests being on 10 c.c. samples.

In the preceding tables one sample has been omitted in striking the bacterial averages for the tap in the city during the six years of filtration because of the fact that certain conditions which will be brought out later required the use of river water which affected that sample. The figures presented, therefore, are a true measure of the water of the city during filtration, and show the good work which has been accomplished in removing the bacterial pollution from the water.

The water supply in East Providence is taken from the Ten Mile River, which is a polluted stream receiving sewage from Attleboro, Mass. The condition of this river became such that in 1899, upon the recommendation of the State Board of Health, a mechanical filter plant was installed. The results have been highly satisfactory, showing a reduction from 8 160 bacteria per c.c. in the river to 33 per c.c. in the effluent, or a removal of 99.6 per cent., and complete removal of B. coli communis at all times. These analyses were of monthly samples taken the first eleven months of this year. In addition to this efficiency for bacterial removal, the plant at the same time reduced the color from 61 in the case of the raw water to 6 in the filtered water, or a removal of 90.1 per cent.

From the above, it has been plainly shown what can be accomplished by either slow sand filtration or mechanical filtration in removing dangers from bacterial pollution of water supplies, and it would seem to indicate very little choice between the two systems from the standpoint of removals effected, but with the advantage in favor of mechanical filtration from the standpoint of removal of color from water high in organic material. I will not attempt to go into a discussion of the relative merits of these

two systems of purification, as that is not the subject of this paper, but I will simply say that each system is efficient under certain conditions, and local conditions should, in all instances, assist in the selection of one or the other method.

As an instance to illustrate the use of filters for removal of color, I would cite the case of the plant at East Warren, R. I., where during 1911 the color in the raw water averaged 74, and was reduced by the mechanical filters to 11, or a removal of 85.1 per cent. This plant is an illustration of a case where slow sand filters, while they would have delivered a sanitary output, in a short time would have experienced trouble from algæ present, and the output would not have given satisfaction to the consumers because the water would still have been highly colored instead of being practically colorless as is the present condition.

At Newport, R. I., there is a mechanical filter plant which has been installed to serve a double purpose of removing bacterial pollution and also to remove odors due to algæ. This is an up-to-date plant in every way, using a system involving aëration, coagulation, and sedimentation, followed by filtration and then disinfection of the supply with hypochlorite of lime. The color of this water is comparatively low, and the resulting output is of good appearance, when the plant is being operated up to its possibilities, and the effluent is largely free from algæ and odor troubles. Likewise, the water is reduced as to bacterial count to a point where it is practically sterile.

Next passing to the question of concrete instances of installations for the removal of iron, I would mention the plant at Marblehead, Mass., where by the use of aëration and filtration through sand the color of the water is improved from a rusty appearance to a practically colorless water, and the iron is reduced from 4.70 parts per million to .06 parts, or a removal of 98.7 per cent. One installation has come under my personal observation where the particular apparatus above referred to, which employs a double-cylinder filter using sand and animal charcoal, showed a removal of iron from 8.00 parts to .10 parts, or 98.75 per cent. removal, with accompanying improvement in the appearance of the water.

In connection with the use of filters in the purification of water

for industrial purposes, I would say that I have been in touch with a number of installations where mechanical filters have been installed of different types which, when properly operated under proper supervision, turn out a product which gives entire satisfaction and shows purification in every way comparable with the results above given.

In treating the second part of my subject, namely, the abuses of water filtration, I would call attention to a number of ways of abuse which might lead to criticism of the whole idea of filtration, but in citing these cases where such abuses have occurred, for obvious reasons I will refrain from naming the installations in most cases.

In the case of slow sand filtration, one would consider it an abuse to attempt to purify a water high in algæ content which would result in clogging of the beds and a general upsetting of operating conditions at the plant. Of course, double slow sand filtration, especially if in connection with aëration, would qualify this previous statement, as aëration and a pre-filter would put the water in condition where it could be handled by the secondary filters, but where aëration followed by coagulation and sedimentation and filtration by mechanical filters would obviate all of the trouble due to clogging of the beds, it would seem as if it was abusing the at times satisfactory method of slow sand filtration to attempt to handle such a water by simple slow sand filtration.

It would also seem an abuse of this method to use it in connection with filtration of highly colored water, which would subject the method to criticism on account of the unsatisfactory appearance of the output.

Another abuse of this method in connection with operation of the filters is too quick changing of rates of operation, which tends to disturb the bacterial action going on at the surface with attendant poor results from an analytical standpoint. Also attempting to overcrowd the filters by running at too high rates is a practice which is sometimes met with, which results in diminution of the efficiency of the plants.

A slow sand filtration plant which would handle a given water satisfactorily might, as was the case in Providence, be installed without covering the beds. Such an installation as this in this

section of the country is certainly an abuse of the method, for the result invariably would be what was found in Providence, that as soon as a hard winter struck the plant the beds would become covered with ice and it would be impossible to get at the surface to clean without removal of the cakes of ice. This condition occurred in Providence for a short time during February, 1907, finally necessitating opening the river gate, and the use of raw water for about two weeks or so before the weather moderated and before the ice could be removed. This experience resulted in steps immediately being taken to cover the beds, and this experience should serve as a lesson against such open installations in this section of the country.

In connection with slow sand plants, it is necessary to have competent help administering the plant, and one of the easiest ways to abuse a plant is to put it into the hands of inexperienced operators.

The above remark about labor in connection with plants is especially true in the case of mechanical filters where the supervision must be particularly close and where tests for color and alkalinity must be made to regulate the doses of chemicals used.

One of these plants which has come under my observation had operated for a number of years satisfactorily, turning out a water which had given entire satisfaction in connection with work in a bleachery. When I was consulted with regard to difficulties which were occurring, I found that the only trouble was that the parties in charge did not have an understanding of the question of alkalinity control of the plant, and the residual alkalinity of the effluent had dropped to a point where the water was passing the plant at times in an acid condition, or at best with an extremely low alkalinity, resulting in after-coagulation in the vats and throughout the system. This condition had been caused by the fact that a certain mill above them had been discharging a larger amount of acid wastes in the river than at the time their formula for operating was figured for them. Not knowing how to vary the dose from time to time, they had stuck to the old formula with the resulting poor work until corrective measures were taken. The addition of alkalinity to the water put the plant back into its former good condition.

At another installation concerning which I had been consulted, I found another condition which was causing trouble. The responsible man in charge of the plant for some reason or other was assigned to night duty, and he was attempting to make his control tests for color and alkalinity at night by artificial light. This, of course, gave far from accurate results. Another trouble at this plant was that the one man was expected to operate the flow of chemicals from the tanks which were located in the pump house and at the same time attend to washing the filters in a filter house which was located about one eighth of a mile away. This spreading out of the plant made it impossible for the lone operator to properly attend to the dosing, and the result was that the flow of chemicals varied from time to time, with resulting poor output from the plant. Here, too, I found trouble in connection with the dosing, for the formula they were using to operate by had evidently been recommended without a knowledge of the water to be handled, and they too were operating with a too low residual alkalinity.

At another plant this same trouble as to a low residual alkalinity was found to exist, and the output contained undecomposed sulphate of alumina. Investigation showed that this operator was using an indicator solution many times too strong, and the alkalinity tests which he was obtaining were absolutely inaccurate. They also were not showing intelligence with regard to the necessity of increasing the doses of chemicals to meet varying conditions in the raw water. Corrective measures, recommended by the State Board of Health, and instruction of the operator, has resulted in this plant turning out one of the best outputs in our state at the present time.

At still another plant the biggest difficulty discovered when troubles arose seemed to be with the application of the chemicals, which in this plant required an extremely close control on account of an influence on the color of the filtered water as the residual alkalinity became too high. The engineer who was employed when this plant started was a man who had been for years pumping water out of the reservoir under the old system, and he could not be made to realize that careful supervision was necessary, and grossly neglected controlling the flow of the chemicals. These

operating troubles immediately ceased when a new, competent engineer was put in charge of the plant.

The effect of an abnormal amount of organic matter or algæ in comparison with the color of the water sometimes has resulted in an under dosing with coagulant, as this additional amount of organic matter has seemed to prevent proper coagulation with resulting incomplete removal of the constituents which it was intended to remove, and the effluent has contained alumina and abnormal amounts of color and algæ. Proper dosing in view of the above-mentioned conditions has resulted in excellent work from this plant.

Another abuse is oftentimes attempting to operate a plant, with every possibility for good results, by methods which some man of limited experience may have used at some other plant, meeting entirely different conditions. Such cases have occurred under my observation, but have been capable of adjustment when instructions have been given which had in mind the type of plant and the raw water to be handled.

In connection with the operation of plants of the mechanical type, it is essential that the night man should be one who can be depended upon to stay awake, as a nap for an hour or two may result in throwing the whole operation of the plant out of adjustment for several hours. I have had my experience with this trouble.

Having thus brought out the conditions which call for filtration of water supplies and having shown the good results obtained with certain installations, I have also attempted to point out a number of ways in which filtration plants are at times abused. One or more instances of abuse are sometimes the only cases of filter plants coming to the attention of some people who immediately condemn the possibilities of the whole proposition of water purification on this meager knowledge.

I would take this opportunity to warn you water-works men against such conclusions from knowledge of some plant or plants which may not be doing all that has been claimed for them. I would also particularly caution that you do not take the cases of abuse which I have mentioned as indicative of any lack of confidence on my part in the ability of plants to purify water satis-

factorily when the following essential points have been observed: first, have the choice of the system and the general outline and construction of the plant in the hands of competent consulting engineers who are experts in these matters; next, having obtained the plant properly constructed and designed to handle the water to be filtered, obtain the best possible men to oversee and run the plant after instruction from competent specialists, and if trouble occurs, call in advice to straighten out the difficulty instead of experimenting blindly; and last, throughout the whole operation of the plant bear in mind that you are handling an efficient machine capable of results, and not an automatic affair which can be left to its own resources.

DISCUSSION.

Mr. Charles W. Saxe.* I have been troubled quite a little with algæ during the summer months. The principal trouble has been from the stoppage of the beds, due, I think, to the use of too little alum, and I increased the amount to remedy that difficulty. Otherwise the results have been excellent. The plant is now delivering practically sterile water, as Mr. Pratt says. I very seldom find coli in the raw water, and I have never yet found it in the effluent.

The efficiency of a plant of the rapid type most assuredly depends upon the even running of the coagulant in proper proportion to the flow of raw water. Slap-dash doses of the coagulant do not prove out very well, especially with water containing algæ, dead or alive. For uniform bactericidal action, the hypochlorite solution must also be run at an absolutely even rate.

Outside of these necessities and the correct estimation of dosings, there are few other vital things for efficiency.

Mr. R. S. Weston † (*by letter*). Mr. Pratt, in his capacity of chemist of the Rhode Island State Board of Health, has had perhaps a better opportunity to observe the operation of various sorts and kinds of water purification plants than any other man in a similar position. While there are practically no muddy rivers in Rhode Island, there are many polluted ones, besides

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* Chemist in charge of Filtration Plant, Newport, R. I.
† Sanitary expert, Boston, Mass.

sources which are contaminated with growths of algæ, other microscopic plants and animals, and with the wastes of the most densely populated state in North America. That Mr. Pratt has not neglected his opportunity, this paper is an evidence.

It is well to emphasize again Mr. Pratt's advice as to the necessity of designing a plant to suit the water to be purified and not in accordance with some general "cure-all" theory which may have no bearing in the particular case; also his insistence upon careful and responsible operators of filters and the analytical control thereof. There are few states, however, where advice is so freely and promptly given as in Rhode Island, and to the writer's knowledge this efficiency has kept at least one filter plant from failure.

Mr. Pratt mentions many of the abuses of filtration and has covered the ground. In connection with the removal of algæ, however, he does not mention the use of intermittent filters such as were used at Springfield. Here, as is well known, experiments demonstrated that any single system of filtration was inadequate to remove taste and odor. It was because of this experience that the writer thought that intermittent sand filters with aëration were best suited for the purification of the Newport supply, grossly contaminated with algæ, and he still believes that without the use of hypochlorite the operation of the present mechanical filters would be impracticable, although with it they present some advantages.

The writer had one experience with double filtration through sand and charcoal in 1895, at Asbury Park, N. J. These filters were used for the deferrization of the water, and it was found that at times iron was absorbed by the charcoal filter and at times given off. The charcoal was replaced with sand, and results were obtained equal to the best — and far better than the average with charcoal. New charcoal, however, removed more iron than new sand.

Most water purification experts spend half their time in correcting the errors mentioned in this timely paper, which, if read and taken to heart as it deserves to be, will tend to prevent many of the mistakes of the past and conserve the public energy in the future.

Mr. H. W. Clark * (*by letter*). I have little comment to make in regard to the main part of Mr. Pratt's paper. We all know at the present time that there is a place for slow filters and a place for rapid filters with the use of coagulants, and the paper brings out forcibly many points in regard to correct operation of filter plants.

I think, however, that he is incorrect in his statement that it is " an abuse to attempt to purify [by a slow sand filter plant] a water high in algæ content, which would result in clogging of the beds and a general upsetting of the operating conditions at the plant." While I have had a considerable acquaintance with reservoirs in which enormous growths of microscopical organisms occur from time to time, the two most prominent in this respect in my mind are the Ludlow Reservoir, a part of the water supply of Springfield, Mass., and the reservoir of the water supply of South Norwalk, Conn. Both of these waters have been successfully and economically filtered by slow sand filter plants; that at Ludlow by single sand filters, and that at South Norwalk by double sand filters. Experiments made at Ludlow by the State Board of Health, and afterwards by the Springfield Water Board, with Fuller and Gray as consulting engineers, ten or more years ago, showed clearly that sand filters were much more efficient in the removal of organisms, tastes, and odors than mechanical filters when handling such waters, and following these experiments, the sand filters mentioned above were installed at Springfield, and about the same time the sand filters were built at South Norwalk, Conn. Both plants have been absolutely efficient and economical when filtering two reservoir waters seriously polluted with microscopical organisms.

Mr. Pratt says also that it is " an abuse of this method [slow sand filtration] to use it in connection with a highly colored water on account of the unsatisfactory appearance of the output." As a matter of fact, this statement needs some qualification. Two of the most highly colored waters purified by filtration in New England are the reservoirs just mentioned. At times in the summer months, the colors of these reservoirs approach or exceed 100, but owing to the nature of this coloring matter and the presence of iron in the water, more than 80 per cent. of it is

* Chemist, Massachusetts State Board of Health.

often removed by single slow sand filtration, and at South Norwalk, double filtration produces a practically colorless water. With the ordinary highly colored river or swamp water, Mr. Pratt's statement is, of course, much more true.

Mr. George C. Whipple* (*by letter*). The writer has been very much interested in Mr. Pratt's paper. Papers of this character need to be published about once in so often in order that the importance of proper operation of filters may be kept fresh in our minds. One of the things that sanitary engineers most lack is adequate information in regard to the results obtained by different filter plants under the special conditions under which they operate. The New England Water Works Association has done a good work in standardizing reports of various kinds, and the writer would be glad to see this subject taken up by an appropriate committee, and studied with a view to standardization of the results of filter operation.

One point mentioned by Mr. Pratt is of particular interest, namely, that the filtration of the Pawtuxet River water by the Providence sand filter removes the vegetable odor of the water, although it does not decolorize it. This suggests that the vegetable odor may be due more to the suspended and collodial matter than to the organic matter in solution. If Mr. Pratt could furnish further information in regard to this matter, it would be of interest to many of us.

Mr. Pratt (*by letter*). Taking up a few points raised by Mr. Clark, I would say with regard to his comments upon my remark in connection with removal of color, that I had in mind handling a reservoir which at times goes up to 180 in true color, and in this case slow sand filters were considered for a time as a means of purification. I consider that it would have been an abuse of slow sand filtration to have tried it with this water or with waters even approaching 100 in color. I think also that Mr. Clark unintentionally misleads somewhat in his mention of 80 per cent. color removal by slow sand filtration. My experience in removal of true color has been that 30 to 40 per cent. is considered extremely good for the method. Of course, with algæ-infected or iron-bearing

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waters having a high apparent color in comparison with the true color, removals of apparent color might easily give higher figures.

As to Mr. Clark's criticism of my statement in regard to the treatment of algæ-infected waters, I would say that, in my complete statement on this matter, I was careful to state that the use of mechanical filters for this purpose should be in conjunction with aëration, coagulation, and sedimentation, and with this system efficient work in removal of color, odor, and taste can be accomplished. Also, I stated that double slow sand filtration especially in connection with aëration might be used. When making the statement that single slow sand filtration would not be efficient I had in mind statements to be found in the reports of the Massachusetts State Board of Health for 1901 and 1905, in connection with the Ludlow Reservoir of the Springfield supply, and there, if I am not mistaken, the position of that board as the result of experimentation was very conservative as to the ability of single slow sand filtration to handle this water at times of extreme algæ content. In fact, they advised against the use of this water as a supply even after filtration. I also had in mind accounts of clogged beds at South Norwalk, Conn., which had come to my attention. If Mr. Clark has now been successful in accomplishing good work at South Norwalk it bears out my statement that double slow sand filtration might be efficient in the case of "algæ" waters, and if the Ludlow Reservoir water has been efficiently handled by single slow sand filters, I think that with waters of that type such a case would be the exception rather than the rule.

With regard to the point raised by Mr. Whipple as to the removal of vegetable odors by the Providence filters, I would say that while these odors are reduced very perceptibly, the filtered water still has a distinct vegetable odor practically all the time. I think the point raised by Mr. Whipple that the reduction is possibly due to removal of suspended and colloidal matters may, in part, account for the reduction, although I think that some of the improvement is due to the reduction in the organic matter in solution, which is materially reduced by the filters as shown by albuminoid ammonia tests and oxygen consumed determinations, as well as by the color removal of 30.8 per cent.

CONSTRUCTION OF ARCHED MASONRY DAM AT LAS VEGAS, NEW MEXICO.

BY WILLIAM T. BARNES, CHICAGO REPRESENTATIVE OF METCALF AND EDDY, CONSULTING ENGINEERS.

[*Read December 11, 1912.*]

Las Vegas, the second largest city in our newly adopted state of New Mexico, is situated in the northeastern part of the state along the foothills of the Rocky Mountains, on the Pecos-Arroya and Gallinas rivers, at an elevation of about 6 500 ft. above sea level.

The census of 1910 showed a population of 7 300 as against 6 320 in 1900. The future population, dependent on conditions other than local ones, is difficult to forecast.

The main line of the Atchison, Topeka & Sante Fé Railroad passes through the eastern portion of the city and makes Las Vegas one of its principal division points. It is therefore an important railroad center, distributing supplies to a large tributary area, shipping in turn the products of a large rural district.

The agricultural interests are important, and with the inauguration of large irrigation projects which have already been undertaken by private enterprise, rapid progress should be made in the development of the natural resources of this community. It is anticipated that large beet sugar industries and other industrial enterprises will follow the introduction of irrigation works. It will not be surprising, therefore, if the next decade shows a more rapid increase in the population of this city than did the last.

Las Vegas has already adopted many modern ideas of city planning. In the newer part of the city the houses are built upon substantial lines, well set back from the street on large lots, surrounded by handsome and well-kept lawns dotted here and there with rapid-growing trees.

Although the finances of the city have not as yet permitted of building modern pavements to any considerable extent, the entire city is well provided with modern granolithic sidewalks separated from the curb by wide areas of sod, in which are planted quick-growing shade trees, thus presenting a very attractive and enterprising appearance.

Water Supply.

Water is supplied to the community by the Agua Pura Company. The source of the supply is the Gallinas River at a point about nine miles north of the city, in the narrow confines of the Gallinas Cañon. The Agua Pura Company is also a dealer in ice, which it furnishes not only to the local community, but also to the Atchison, Topeka & Santa Fé Railroad, the needs of which it supplies for several hundred miles in either direction from Las Vegas. It has built nine dams in the bed of the Gallinas River for the purpose of ice production. In one of the reservoirs thus produced, known as No. 8 reservoir, is located the water-works intake. From this intake the water flows through an open canal along the borders of the reservoir, for a distance of one-half mile, where it enters a small settling basin, where racks and screens protect the inlet to the main supply pipe. From this point, which is at an elevation of 410 ft. above the general city level, the water flows 5.1 miles through a 12-in. pipe to a distributing reservoir two miles north of the city and at an elevation of approximately 281 ft. above the city level. From this reservoir the water is distributed to the pipe system of the city by two circuits, thus insuring the city ample pressure, and safety in case of need of repairs to either of these pipe lines.

Drainage Area.

The drainage area tributary to the intake is about 90 sq. miles, as determined from the topographical maps of the United States Geological Survey.

Records of Rainfall.

With exceptions during the years 1890 and 1891 only, the government record of monthly and yearly precipitation in the city of

TABLE 1.

MONTHLY AND YEARLY PRECIPITATION, EAST LAS VEGAS, NEW MEXICO.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1892	1.22	0.07	1.72	0.41	0.54	1.01	2.28	0.79	0.48	1.31	0.05		
1893	0.18	1.06	0.07		1.50	0.25	5.64	6.97	3.87	0.04	0	0.31	19.99
1894	0.10	1.66	0.04	0.54	2.53	2.82	2.89	4.05	1.22	0.08	0	0.28	16.21
1895	1.00	1.85	0.30	0.52	4.02	1.98	6.85	5.32	T	1.12	0.88	0.82	24.66
1896	0.19	0.32	0.83	1.00	0.11	2.02	3.87	2.13	4.38	4.35	0.02	0.51	19.73
1897	0.69	0.70	1.43	0.37	6.63	1.23	1.18	3.29	0.79	1.94	0	0.59	18.84
1898	0.51	0.21	0.49	1.41	1.04	2.74	4.63	2.97	1.29	0.33	0.57	0.80	16.99
1899	T	0.73	0.70	0.21	0.40	2.65	7.09	0.17	2.87	0.52	0.43	0.09	15.86
1900	0.19	0.25	0.59	2.25	1.87	3.59	2.70	2.23	4.27	1.98	0.30	0.46	20.68
1901	0.27	0.70	0.14	1.17	5.55	0.19	3.70	4.95	2.00	1.40	1.78	0.30	22.15
1902	0.10	0.10	0.01	0.06	1.95	0.30	1.91	1.83	1.33	0.47	0.79	0.93	9.78
1903	0.07	1.42	0.13	0.52	0.22	6.24	1.41	3.57	1.11	0	T	0.12	14.81
1904	0.20	0.20	T	0.24	0.97	3.20	4.95	0.68	6.07	1.08	0.05	1.10	18.74
1905	1.45	1.84	2.13	3.07	2.04	1.56	1.70	1.34	4.25	0.48	3.32	0.68	23.86
1906	0.04	1.02	0.47	2.17	1.08	2.80	7.82	1.97	1.86	1.67	0.86	1.32	23.08
1907	1.57	0.01	0.07	2.13	2.57	0.77	5.57	3.30	0.22	0.82	0.77	0.20	18.00
1908	0.14	1.05	0.05	1.12	0.68	1.13	2.71	9.24	0.06	0.76	0.96	0.26	18.16
1909	0.17	0.49	1.00	0.50	0.51	0.51	1.53	5.99	3.91	0.76	0.19	0.44	16.00
1910	0.16	0.30	0.61	0.98	0.13	0.31	2.48	3.72	1.08	0.85	0.45		11.07
1911	0.11	1.33	0.18	0.93	2.41	2.44	3.55	2.30	0.68	2.83	0.30	0.93	17.99
Average	0.42	0.77	0.55	1.03	1.84	1.89	3.72	3.34	2.09	1.14	0.59	0.56	18.00±

* From Weather Bureau Reports, New Mexico Section.

TABLE 2.

MONTHLY AND YEARLY PRECIPITATION, GALLINAS PLANTING STATION, NEW MEXICO.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1908	0.56	1.53	1.30	3.23	1.05	0.58	5.10	5.71	0.28	1.09	1.13	0.44	22.00
1909	0.69	0.61	1.54	0.55	0.66	1.71	5.11	6.98	2.86	1.07	0.97	0.66	23.41
1910	0.62	0.76	0.65	1.63	1.54	2.49	5.59	3.96	1.86	1.27	0.69	0.42	21.48
1911	1.00	1.91	0.72		2.54	1.20	9.01	2.38	0.61	3.42	0.82	0.98	24.59
Average	0.72	1.20	1.05	1.80	1.45	1.49	6.20	4.76	1.40	1.71	0.90	0.63	22.37

TABLE 3.

MONTHLY AND YEARLY PRECIPITATION, HARVEY'S UPPER RANCH, NEW MEXICO.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Annual.
1910	1.42		1.18	2.70	1.29	2.31	3.87	6.56	1.92	2.43	0.87	1.60	26.15
1911	1.20	3.04	2.03	2.13	2.70	3.80	8.32	3.08	2.05	6.86	1.20	1.68	38.09
Average	1.31	?	1.61	2.41	2.00	3.05	6.10	4.82	1.98	4.65	1.04	1.64	32.12

Las Vegas is continuous since the year 1889, as recorded in Table 1. From these records it appears that the average yearly rainfall is about $18\frac{1}{2}$ in., the maximum being $24\frac{1}{2}$ in., the minimum slightly less than 10 in. The bulk of the precipitation occurs during the so-called "rainy season," which includes the months of July and August, and sometimes parts of June and September.

Records of precipitation were kept at the Las Vegas Hot Spring from June, 1898, to July 1903, but the omissions in the records are so frequent as to prevent their satisfactory use.

At the Gallinas Planting Station in the Gallinas valley, a few miles above the water-works intake, the records have been systematically preserved since January, 1908, as recorded in Table 2, while at Harvey's Upper Ranch near the headwaters of the Gallinas River the records, with exception of one month, have been kept with regularity since January 1, 1910, and are recorded in Table 3.

The short periods during which the records have been maintained prevents the drawing of accurate conclusions, but are sufficient to show that the amounts of precipitation increase with the elevation, especially during the winter and spring months.

This increased precipitation is mainly in the form of snow, which melts gradually during the spring months, the run-off accordingly tends to be more evenly distributed during the spring and early summer.

Yield and Its Variation.

The United States Geological Survey has maintained a gaging station on the Gallinas River at the Las Vegas Hot Springs about 7 miles above the city of Las Vegas and about 2 miles below the intake of the water works, since August, 1903, and these records are available to and including the year 1910.

The records for the year 1904 show that, prior to the storm and flood September 29 to October 1, there was practically no flow in the stream, and after the flood subsided there was but a slight flow.

In Table 4 are recorded the minimum and mean rates of flow in million gallons per day for each month, and by years from 1905 to 1910 inclusive. From this table it appears that there have

TABLE 4.

DISCHARGE OF GALLINAS CREEK AT HOT SPRINGS, N. M., SIX MILES ABOVE LAS VEGAS, N. M.*

	Minimum Rate of Discharge, Mil. Gal. Day						Mean Rate of Discharge, Mil. Gal. Day.					
	1905.	1906.	1907.	1908.	1909.	1910.	1905.	1906.	1907.	1908.	1909.	1910.
January	7.7	2.6	4.6	0.8	1.2	1.2	7.7	5.9	8.8	1.9	2.8	3.2
February	7.7	5.2	9.0	0.8	1.2	1.2	25.8	7.2	9.6	3.6	2.6	2.8
March	36.8	9.0	9.0	2.3	2.2	3.2	60.3	16.7	17.8	4.6	7.5	13.8
April	48.4	33.2	16.1	2.3	3.2	6.8	114.2	63.7	28.1	19.0	15.1	19.7
May	78.1	41.3	35.5	12.9	9.7	3.2	133.0	71.0	59.0	17.7	15.9	14.1
June	12.9	5.2	9.0	2.6	1.3	0.2	40.9	20.3	41.3	6.9	4.3	1.3
July	7.7	5.2	6.8	2.6	1.3	0.2	11.2	24.8	16.0	10.1	7.1	3.2
August	7.7	9.0	4.6	18.8	4.5	1.2	17.2	14.0	17.6	41.9	21.1	8.0
September	3.9	5.2	4.6	3.2	0.2	0.2	9.0	9.5	14.7	7.9	26.8	1.5
October	1.3	1.3	0.0	0.0	0.0	0.2	2.3	11.0	1.1	0.5	3.8	0.2
November	1.3	9.0	0.8	0.2	0.2	0.2	20.7	10.1	2.0	0.9	3.0	0.2
December	7.7	9.0	2.3	3.2	1.2	0.2	12.1	28.4	2.3	3.2	2.4	0.2
For year	1.3	1.3	0.0	0.0	0.0	0.2	37.3	23.2	18.2	9.8	9.4	5.7

See Water Supply and Irrigation Papers as follows:

Paper No.	174	210	248	248	268	288
Page	115	98	137	137	95	127

* Gaging station is located two miles below intake of water works, and these flows do not include that diverted for water-works purposes.

been a number of occasions when the flow at this point would have been insufficient to materially augment the water supply. In fact, the records of the years 1904 and 1910 clearly indicate that additional storage was absolutely necessary in order to secure a permanent water supply.

Water Consumption.

No facilities exist for accurately determining the amount of water consumed, as the supply is wholly by gravity without meters on the main supply lines. From such records as have been obtained from time to time of the flow in the open canal, it is believed that the maximum rate of consumption is considerably in excess of 2 000 000 gal. per day, and that the average daily consumption is in the neighborhood of 1 500 000 gal. per day. During the season when large volumes are used in " irrigating " the lawns and gardens, the daily consumption is probably about 1 750 000 gal.

Quality of Water.

Draining a rocky mountainous region, flowing through long and narrow gorges, with precipitous bluffs on either side, the Gallinas River naturally supplies very clear and pure water. In times of freshet, however, the water finds its way to the stream with such rapidity that large volumes of gravel, clay, and alluvium are carried in suspension. These freshet conditions are, however, confined in the main to one or two periods of time, of two to three weeks each, during the " rainy season."

Available Means of Safeguarding the Supply.

In order to improve the quality of the water supply, two practicable methods were considered, — filtration and storage.

FILTRATION.

Filtration offered some advantages over simple storage of water. Such a plant could be located within easier reach of the city,

might reduce the hazard of pollution, the suspended matter in the water at certain seasons, the possibility of taste and odor from algæ or other forms of growth, and might effect a saving in initial expenditure.

On the other hand, the filter plant had the disadvantage of not providing additional storage to supplement the minimum stream flow, a matter of increasing importance as the population and demand for water grows, and unfortunately involved far greater cost of operation and maintenance than did the project for a storage reservoir.

STORAGE.

Two sites for a storage reservoir were available in small lateral cañons tributary to the Gallinas River, one at a point abreast of Placita Llano, the other in a cañon or valley near the "Hot Springs," owned by the Cañon Lime Company.

Although the first location offered a good dam site, the comparatively steep slope of the cañon prevented the development of ample storage except at great expense.

The valley belonging to the Cañon Lime Company was admirably suited for a reservoir. Its mouth, a cañon through a quartzite ridge, running in a generally northerly and southerly direction, formed a natural site for a dam. The slope of the bed of the valley was sufficiently flat so that the basin formed by the dam was well adapted to a storage reservoir, and of much importance was the fact that this valley had no stream running through it except that created during the rainy season, by the rain falling within a very small watershed.

The drainage area was small, only 3.0 sq. miles. Therefore the run-off from it was practically insignificant, thus making it possible to collect and divert the storm flows upon it in a channel built around the edge of a reservoir, discharging them below the site of the dam and preventing the fouling of the clear water stored in the reservoir. This reservoir could be filled by means of a small canal or ditch, having an approximate capacity of 10.0 cu. ft. per sec., which would carry the water diverted during periods when the waters are clear, thus making available at all times a clear water as well as affording ample storage capacity.

Storage Reservoir Adopted.

In view of these advantages, the storage reservoir was adopted in preference to the filtration plant, and the dam was built at the mouth of the Cañon Lime Company's cañon.

Design of Dam.

In designing the dam, three types were considered, — a straight gravity section; the hollow reinforced dam of the Ambursen type; and the arched masonry type.

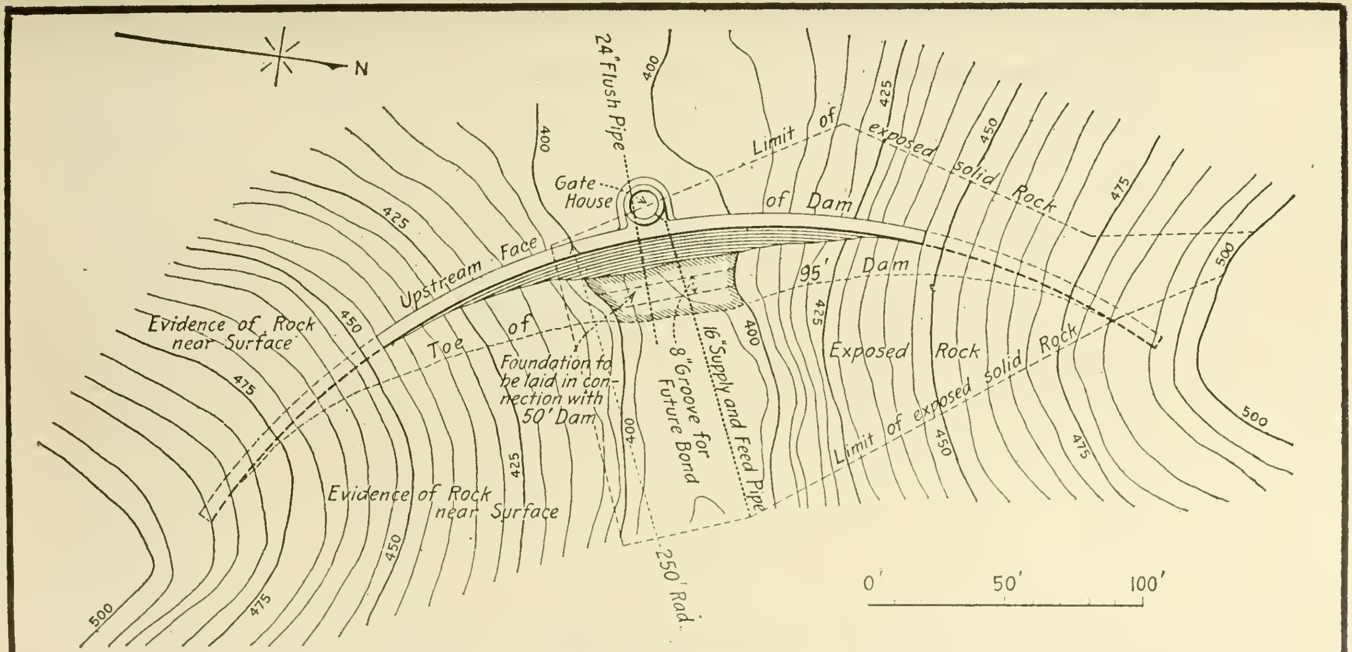
The outcrop of ledge on either side of the cañon, at the site selected for the dam, indicated that a very firm and solid foundation could be secured, as proved to be the case.

As a storage capacity of 60 000 000 gal. would serve the immediate needs of the water company and would probably be sufficient for a number of years to come, whereas ultimately a much larger storage would be required, it was desirable to decide upon a type of dam which could be built to such a height as to give this storage at the present time, with the provision that at some future time, the height of the dam could be increased sufficiently to give the additional amount of storage then required. A 50-ft. dam was sufficient to afford 68 000 000 gal. storage, while the site is such as to allow the construction of a dam 95 ft. in height, which would retain some 425 000 000 gal.

In order to provide for the ultimate increase in the height of the dam, it would have been necessary, had the Ambursen type been selected, to build the entire low level dam on the lines of the high level structure, whereas it was possible to design a solid concrete arched structure on lines suitable for the lower dam with the provision that ultimately this dam could be incorporated into and made part of a higher structure without increased present expenditure. Accordingly it was decided to construct a solid unreinforced concrete arched dam with a radius of 250 ft. and 50 ft. above the bed of the stream. See Figs. 14 and 15.

A comparison of the section of this dam with the sections of other similar structures appears in Table 5.

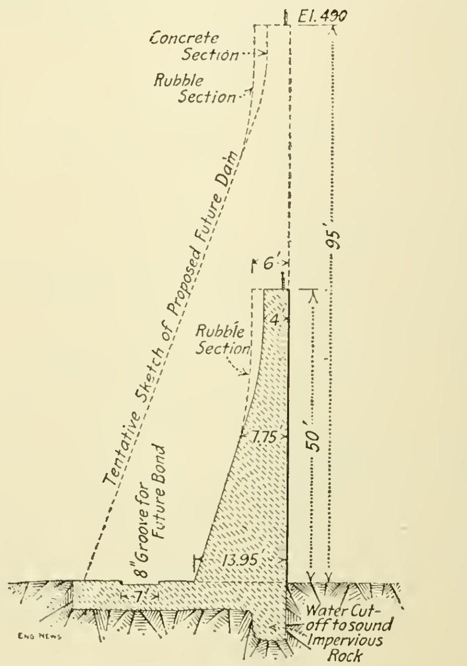
For further details upon the design of this structure reference



PLAN OF THE ARCHED CONCRETE DAM FOR THE AGUA PURA CO., LAS VEGAS, N.M.

Fig. 14.

can be had to a paper by Charles W. Sherman, in *Engineering News* of October 27, 1910.



Section Through Crown of Present 50-Ft. and Proposed 95-Ft. Las Vegas Arched Dam.

FIG. 15.

CONSTRUCTION.

Contract for the construction of the dam was awarded on September 21, 1910, to Mauretz M. Sundt, a local contractor, carpenter, and builder, equipped with a plant sufficient for this undertaking, though his experience had been confined largely to the construction of buildings, foundations, and sidewalks.

Principal Details of Curved Masonry Dams.

Place.	Max. Ht. Ft.	Thickness Base.	Thickness Top.	Max. Stress in Arch. Lb. per Sq. In.	Rad. Upstream Face.	Length Top.	Character of Rock.	Date.
(1) Katoomba, New South Wales	25	20.29	3.0	233	220	320	Sandstone	1905
(1) Picton, New South Wales	28	13.62	7.0	186	120	112	Sandstone	1897
(3) Winchester, Ky.	31	8.58*	4.83	498	318.4	407		
(1) Queen Charlotte Vale, New South Wales	32	8.65	3.0	155	90	113	Quartzite	1898
(1) Parkes, New South Wales	33.5	13.5	3.0	373	300	540	Granite	1897
(1) Lithgow No. 1, New South Wales	35	10.88	3.5	155	100	178	Sandstone	1896
(1) Wollongong, New South Wales	42	11.62	3.5	311	200	535	Basalt	
(1) Cootamundra, New South Wales	46	13.0	3.0	389	250	640	Granite	1898
(1) Wellington, New South Wales	48	10.0	3.0	311	150	350	Conglomerate	1899
(2) Bear Valley, Cal.	48 (Total 64)	8.4 at 48 ft.	3.17	825	335	300	Granite	
(1) Mudgee, New South Wales	50	18.0	3.0	311	253	498	Altered slate	1899
(1) Parramatta, New South Wales	52	15.0	4.8	223	160	225	Sandstone	
(3) Lewiston, Ida.	55.5	14.5	5.33	475	286.5	288		
(1) Tamworth, New South Wales	61	21.5	3.0	311	250	440	Granite	1898
(1) Medlow, New South Wales	65	8.96	3.5	186	60	124	Sandstone	1906
(1) Lithgow No. 2, New South Wales	87	24.0	3.0	155	100	221	Sandstone	1906
(2) Sweetwater, Cal.	90	46	12	188	222	380		
(4) Ithaca, N. Y.	90	7.75		283	67.85		Shale	1903
(2) Barossa, South Australia	95	34	4.5	242	200			1903
(2) Zola, France	119.7	41.82	19.02	196	158	205		
(4) Cheesman, Colo.	210 to 176 H. W.	72.66 at el. 100	18		399.89 at top		Granite	1900
(5) Pathfinder, Wyo.	210	94	10	181	(150 at center) (186.5 at base)			
Las Vegas (under contract)	50	15.50	5.0	350	250	210		1910
(proposed)	95	43.30	5.0	300	250	390	Sandstone	
(6) Cascadilla Creek dam, Ithaca, N. Y.	25	40	2.5	189	70	96	Shale	1904
(7) Upper Otay, Cal.	75	14	4	604	359	350		1900
(8) Crowley Creek, Malheur Co., Ore.	60	5.2	3.0	350	70	170		1898

(1) *Eng. News*, May 19, 1910.
(2) Wegman's "Dams," 5th edition.
(3) Data obtained from Wm. Wheeler, engineer.
(4) Trans. Am. Soc. C. E., Vol. 53.
(5) Jour. N. E. W. W. Association, June, 1906.
(6) *Eng. News*, November 10, 1910.
(7) Schuyler's "Reservoirs," 2d edition.
(8) *Eng. News*, August 24, 1911, p. 220.
* 15 ft. above base.

LABOR.

The labor employed upon the work was almost entirely Mexican, drawn from the immediate neighborhood, and was paid at the rate of $1.50 per day of ten hours.

EXCAVATION.

Work was begun, September 28, 1910, by stripping the earth from practically the entire site of the dam. The earth was thrown out upon the downstream side of the excavation, and the rock on the upstream side and rolled down the hill to the valley, where it was picked up and hauled to the crusher. About one fourth of the entire excavation (or, more particularly, 245 cu. yd.) was classified as earth excavation and was paid for at the contract price of 80 cents per cu. yd.

The rock excavation consisted of a fine, close-grained quartzite, lying below the surface at depths varying from a few inches to 6 ft., as shown in the accompanying photograph, Plate XVI, which also shows the ledge inclined or dipping to the west, or toward the reservoir, with an inclination of about 60 degrees with the horizontal.

In order to avoid the excavation of the ledge below the dam within the bed of the stream when it may prove desirable to raise the dam to a higher level, the ledge found in the river bed was excavated to an average depth of 6 ft. for the entire width necessary for the ultimate 95-ft. dam, said excavation being carried well into the side walls of the cañon and filled with concrete as shown in Plate XVI.

Concrete.

The concrete plant consisted of a Chicago Improved Cube Mixer, of $\frac{1}{2}$-cu. yd. capacity. The stone was crushed at the site of the work by means of a small portable crusher.

ARRANGEMENT OF PLANT.

At the beginning of the work, in order to utilize the rock which was excavated from the site of the dam, the crusher was located about 100 ft. west of the face of the dam, within the reservoir site,

EXCAVATION FOR FOUNDATIONS AT SOUTHEASTERLY END OF DAM.

while the mixer was placed between the crusher and the site of the dam, the crushed stone being piled in close proximity to the mixer.

This location proved to be extremely convenient for the first three weeks, or until a height was reached that made the incline of the runway too steep for the wheelbarrows.

CRUSHED STONE.

In order to provide sufficient stone for the crusher, a quarry was selected within the reservoir basin, on the south side of the cañon and about 100 ft. westerly of the site of the dam. When the stone from the excavation was exhausted, the crusher was moved back, and the rock, as excavated from the quarry, was rolled down the hill, broken by means of large hammers, and fed to the crusher in its new location. At the same time (December 6) the mixing plant was also moved further from the dam, this position being adopted in order to make possible the erection of a runway for the wheelbarrows which would be sufficiently flat to permit of easy wheeling, even after the dam was well advanced.

By December 30, after three weeks' service in the second location, the runway again became too steep, and it became necessary to select a third location for the mixing plant.

As the quarry selected had developed a very inferior grade of stone, and as good material was difficult of access, the contractor decided, at the engineer's suggestion, to locate his plant on the opposite side of the valley, on top of the hill in line with the dam and near the newly constructed roadway over which it was necessary for all the sand to be carted.

By adopting this location, it was possible to save the expense of wheeling partly filled wheelbarrows of concrete up a long and tedious incline, and the operations of crushing and mixing were reduced to a minimum of labor and of effort. The expense of hauling the sand completely over the hill and down into the valley was also partly eliminated, as the teams could, in this new location, dump their load on top of the hill, thus making nearly twice as many trips as was possible in the second location.

Accordingly, the plant was moved during the first week in January to its third position, on the top of the hill, as shown in

Plate XVII. A terrace was constructed on the side of the hill, on which the mixing platform was built, of such a size and at such an elevation below the level of the roadway in which the crusher was placed as to provide ample storage for fully a day's supply of crushed stone. The mixer was located at a lower level so that the mixing platform was level with the top of the feeding hopper. The quarry was established on the top of the hill, where there was found an ample supply of very satisfactory stone. As the stone thus quarried was within easy reach of the crusher, the handling of materials was reduced to a minimum from the time the stone was quarried until it was dumped from the mixer directly into a long chute which led directly from the mixer to a distributing box just above the wheeling platform constructed on the top of the forms.

The loading of concrete into wheelbarrows was controlled by a shear gate in this distributing box by means of which each batch of concrete was disposed of as rapidly as it was mixed, while separate runways for the loaded and empty wheelbarrows made it possible to distribute the concrete with a minimum of labor.

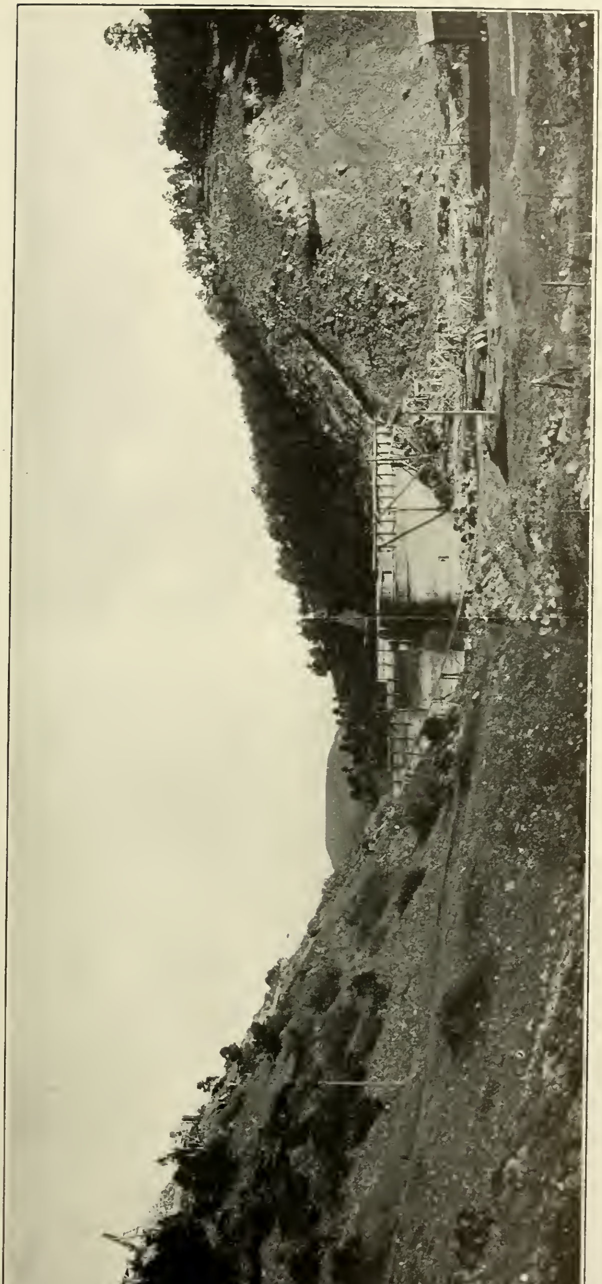
By this arrangement about twice as much concrete was mixed and placed per day as the same force of men had been able to do during the latter part of the time when the mixing plant was in its second position.

RELATIVE OUTPUT DURING DIFFERENT PERIODS.

In order to determine the relative amounts of labor employed in the several subdivisions of the work during each of the three periods of construction, a mass diagram has been prepared, as shown in Fig. 16. The three periods above referred to are determined by the location of the plant, namely, first period, with mixing machinery near the site of the dam; second, with machinery, including the crusher, in the valley at some distance from the dam, and third, with entire outfit on top of the hill in line with the dam.

The mass diagram was constructed with accumulated volumes of concrete in cubic yards, as abscissæ, and the accumulated amount of labor expended, as ordinates. The records of labor

Plate XVII.
N. E. W. W. Association.
Vol. XXVI.
Barnes on
Las Vegas Dam.



View of Partly Completed Dam from Reservoir Site.

employed in the following subdivisions of the work, namely, quarrying, crushing stone, concrete mixing and placing, and stagings and forms, have been plotted in terms of the corresponding amounts of concrete placed. These points have been connected, forming an irregular line, while the average condition for each

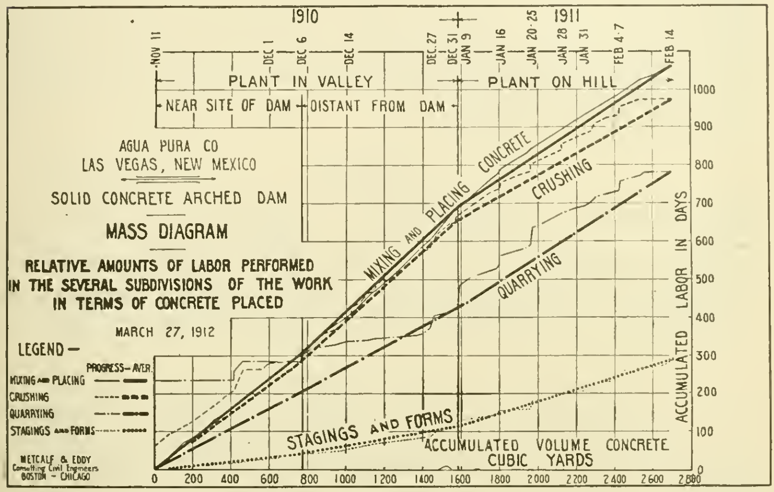


Fig. 16.

period, for each subdivision of work, has been shown by a straight line of heavy weight. These data are expressed in tabular form, Table 6.

QUARRYING.

The quarry was well advanced when concreting began, 230 days of labor having been performed, while all of the stone quarried was consumed by December 31, at which time 1 582 cu. yd. of concrete had been placed, with a total expenditure of 424 days of labor in quarrying. The amount of concrete laid per laborer employed in the quarry is indicated by the slope of the line drawn from the origin to the point whose coördinates are 1 582; 424. In other words, 3.73 cu. yd. of concrete were laid during this period per day's labor employed in the quarry. Similarly, we find that

3.14 cu. yd. of concrete were laid after January 1 for each day of labor employed in the new quarry upon the top of the hill.

STONE CRUSHING.

In the same manner we find that during the first period of construction 2.60 cu. yd. of concrete were laid for each day of labor employed in crushing stone, whereas during the second period only 2.28 cu. yd. of concrete were laid per day of labor, while during the third period, 3.5 cu. yd. of concrete were laid per day of labor in crushing stone.

TABLE 6.

CONSTRUCTION OF ARCHED CONCRETE DAM FOR THE AGUA PURA COMPANY AT LAS VEGAS, N. M. 1910–1911.

Yardage of Concrete placed per Laborer-day expended in the Several Subdivisions of the Work during the Three Periods of Construction, determined by the Relative Positions of the Mixing and Crushing Plants to the Dam.

Subdivision of Work.	First Period.	Second Period.	Third Period.
	Machines in the Valley.		Machines on Top of Hill in Line with Dam.
	Near Dam.	150′ from Dam.	
Quarry	3.73		3.14
Crusher	2.60	2.28	3.50
Concrete mixing and placing	2.52	2.10	3.02
Stagings and forms	20.8	11.0	6.33

CONCRETE MIXING AND PLACING.

Similarly, during the first period 2.52 cu. yd. of concrete were laid for each day of labor employed in mixing and placing, while during the second period only 2.10 cu. yd. were laid, and during the third period 3.02 cu. yd. were laid per day of labor employed in mixing and placing.

STAGINGS AND FORMS.

In connection with the construction of stagings and forms, we find that for each day's labor employed during the first period 20.8 cu. yd. were laid, while during the second period but 11.0

cu. yd. were laid, and that during the third period, only 6.33 cu. yd. were laid for each day of labor employed in building stagings and forms.

QUARRY. — RATE OF PROGRESS.

That the quarrying cost more during the third period than during the first two periods is undoubtedly due to the fact that the carpenters were unable to provide forms during the third period sufficient to furnish the mixing and placing crew with a full day's employment. Consequently, almost every day the labor from this crew were turned into the quarry, which resulted in disorganizing the regular quarry crew, so that the increase in output was not proportionate to the increase in labor employed. Had it not been for this disorganizing effect, or had good foremanship been maintained in the quarry, it is probable that the quarrying during the third period would have been at about the same rate as during the first two periods, or possibly slightly better.

CRUSHED STONE. — RATE OF PROGRESS.

That more yardage were placed per laborer employed in crushing during the first period than during the second, is due to the use of the rock found in the excavation for the dam, which was readily delivered to the crusher. The position of the crushed stone platform in the third period, some ten feet lower than the base of the crushing plant, thus avoiding the congestion of the crushed stone around the crusher, together with the fact that the stone was utilized about as fast as it was crushed, as well as the fact that the raw material was piled conveniently close to the crusher, is sufficient reason to explain the great difference in results during the third period.

CONCRETE. — RATE OF PROGRESS.

The slopes of the lines on the diagram, Fig. 16, representing the mixing and placing of concrete, vary in the different periods about as might be expected, except that during the first period, with the machinery placed at the edge of the excavation and some distance above the bottom thereof, the concrete should have been made and placed under such conditions with far less labor than would be

required after the machinery was moved some 150 ft. from the edge of the excavation in a position which required not only longer wheeling circuits but during most of the time the wheeling of loaded wheelbarrows upgrade, whereas in the first position the bulk of the loads were wheeled downgrade and upon very short circuits.

It is probable that the difference is due to the fact that during this first period a great deal of time was lost on account of leaking flues in the old boiler which supplied the steam for the concrete mixer, thus resulting in the entire crew remaining idle while the engineer cleaned, or rolled, his flues. It is estimated that had the new boiler, which was used during the second period, been made use of from the beginning of the work, the concrete might have been placed during the first period at the rate of 3.5 yd. per day of labor employed.

Although the curve showing the actual conditions during the second period as plotted is not far different from the straight lines showing the average conditions, it is to be noticed that the slope of the line showing actual conditions at the end of the second period is much steeper than the average, and it is believed that had the work continued for another week with the machinery in the second position, the slope would have represented the placing of not more than one yard of concrete per day of labor employed, whereas by moving to the top of the hill it was possible to mix at the rate of three yards per day of labor employed.

The reasons for this improvement have already been alluded to, and may be enumerated as follows: First, the relation of the operating platform, mixer, chutes, and wheeling platform were such as to enable each set of men to perform their respective tasks without interference, and with a minimum of labor. Second, with the operating platform located above the mixing hopper the engine was no longer called upon to raise the "feeding pan" in order to charge the mixer, thus saving both time and steam, as the hopper, which was loaded while the previous batch was being mixed, could be discharged directly into the mixer immediately following the dumping of the previous mix. Third, the wheelbarrow crew could remove and place the concrete as fast as it was mixed, and there was always an ample supply of crushed stone

and sand in close proximity to the mixing hopper, and the water was rapidly supplied through a large valve from a barrel supported over the mixer, so that the whole operation was one that created interest among the workers to the extent that each appeared to desire to have his part of the process ready without causing delay to the operation.

The average output during this third period was at the rate of 36 one-bag, or 0.2 cu. yd., batches per hour, while the maximum day's output was at the rate of 47 batches per hour, which rate was continued for seven hours, and the minimum rate was 26 batches per hour.

FORMS.

It is to be noticed that although there was practically no carpenter work during the first half of the first period, except for the construction of runways, there was nearly as much labor employed per yard of concrete during the first part of this period as was employed during the later portion. This is due in great measure to the same cause as has already been referred to in connection with the making of concrete, namely, an insufficient and worn-out boiler gave the crew frequent opportunities to remain idle.

That more labor was required during the third period than during the second is due to the fact that all of the concrete was delivered to the wheeling crew at the bottom of the incline chute at the north end of the dam, and as the wheeling platforms were supported upon the top of the forms it was impossible to construct new forms at the north end of the dam while the concrete was being delivered to the dam. Accordingly, the concrete mixing was stopped for a day while the carpenters erected the forms at the north end of the dam. While this section was being filled the carpenters then prepared the adjoining section of forms, and while this was being filled they erected the third set of forms, and similarly with the fourth section, so that the fifth day the mixing crew was laid off and the carpenters rushed upon the erection of the northerly set of forms for the next zone, erecting this in one day, in order not to delay the mixing more than one day.

The result was that a large number of inexperienced men were assigned to assist the carpenter in the construction of these forms,

and especially so on the day while the mixer was shut down, as shown by the vertical lines in the diagram which gives a " saw-tooth " effect to the line representing the actual conditions. It is to be noted that were it not for the influx of labor on these special days the " saw-tooth " effect would have been less marked and the slope of this line would have been substantially parallel to the slope of the average line during the second period, thus indicating that the excess cost of stagings and forms during the third period was due in great measure to the superabundance of labor on the days mentioned.

Unit Costs.

Daily cost accounts were kept by the engineer, under the headings of " Excavation " and " Concrete," the latter being subdivided as follows: Quarry, Crushed Stone, Sand, Cement, Mixing, Heating, Wheeling, Placing, Placing Cyclopean Masonry, Water Supply, and Stagings and Forms.

For each of the foregoing subdivisions, separate records were kept under the following headings: " Labor and Teams," " Superintendent, Foreman, and Blacksmith," " Materials and Supplies," and " Tools, Equipment, and Repairs."

In order to make the records as complete and accurate as possible, arrangements were made with the contractor whereby he gave the engineer access to his time-book and furnished monthly statements of amounts and costs of materials furnished and of expense involved in repairs, etc., the items of which were distributed according to the engineer's discretion.

It is believed that the tabulated costs submitted herewith in Tables 7 and 8 represent very closely the actual unit costs upon this work. In Table 9, a summarized statement of costs has been prepared, showing the relation of " cost to the contractor " to the " cost to the Agua Pura Company," indicating the probable profit and loss under the items of earth and rock excavation, concrete, and under the item of extra work. As will be noted from the memorandum attached to this table, these figures include $1 224 extra compensation paid to the contractor for prosecuting the work through the cold weather instead of closing down as the contract permitted him to do.

FIG. 1.
DAM UNDER CONSTRUCTION — DOWNSTREAM FACE.

FIG. 2.
UPSTREAM FACE OF DAM DURING CONSTRUCTION.

TABLE 7.

Agua Pura Company's Dam.

ESTIMATED COST TO CONTRACTOR, FROM BEGINNING TO DECEMBER 31, 1910. (PLANT IN VALLEY.)

Concrete (1 582 cu. yd.).

Item.	Labor and Teams.		Supt., Foreman, and Blacksmith.		Materials and Supplies.		Tools, Equip., and Repairs.		Total Cost.	
	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $
Quarry										
Drilling..	167.85	0.10								
Labor ...	394.78	0.25								
Total..	562.63	0.35	89.57	.06	77.88	.05	13.86	.01	743.94	0.47
Crushing										
Setting up	39.25	.02								
Engineer.	198.20	.13								
Labor and team...	847.65	.54								
Total..	1 085.10	.69	103.20	.07	120.95	.07	439.24	.28	1 699.19	1.11
Sand										
Teams...	306.40	.19								
Labor....	149.60	.10								
Total..	456.00	.29	42.60	.03	3.80		17.11	.01	519.51	0.33
Concrete										
Mixing...	36.00	.02								
Teaming coal ...	6.00									
Engineer.	123.45	.08								
Sand.....	101.20	.07								
Stone....	202.40	.13								
Cement..	50.60	.03								
Water & dump..	101.10	.07								
Total.	620.75	.40	56.60	.03	92.30	.06	366.72	.23	1 136.37	0.72
Heating										
Material.	82.35	.05	8.15		85.05	.06	3.00		178.55	0.11
Wheeling...	351.60	.22	35.10	.02			21.00	.02	407.70	0.26
Placing....	155.85	.10	15.65	.01	31.40	.02	12.60	.01	215.50	0.14
Placing Cyclop....	55.85	.04	5.60				50.50	.03	111.95	0.07
Stage and Forms										
Carpenter	106.50	.06								
Labor....	126.95	.08								
Team....	62.30	.04								
Total..	295.75	.18	22.10	.02	385.10	.24			702.95	0.44
Cement										
Cement shed...	79.80	.05								
Teams...	192.00	.12								
Total..	271.80	0.17	21.30	.02	5 113.00	3.24	82.50	.05	5 505.60	3.48
Total concrete....	3 937.68	2.49	399.87	.26	5 926.48	3.78	1 006.53	.64	11 270.56	7.13

TABLE 8.

AGUA PURA COMPANY'S DAM.

ESTIMATED COST TO CONTRACTOR FOR MONTHS OF JANUARY AND FEBRUARY (TO MARCH 15, 1911). (PLANT ON HILL.)

Concrete (1 121 cu. yd.).

Item.	Labor and Teams.		Supt., Foreman, and Blacksmith.		Materials and Supplies.		Tools, Equip., and Repairs.		Total Cost.	
	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $	Total. $	Unit $
Quarry										
Foreman.	56.00	0.05								
Labor....	497.55	.45								
Team....	36.80	.03								
Total..	590.35	0.53	84.41	.07	18.30	.02	11.20	.01	704.26	.63
Crushing										
Setting up	32.50	.03								
Engineer.	134.50	.12								
Labor....	408.70	.36								
Total..	575.70	.51	72.33	.07	60.40	.05	148.02	.14	856.45	.77
Sand										
Teams...	314.00	.28								
Labor....	128.85	.11								
Total..	442.85	.39	52.56	.05	31.25	.03	13.06	.01	539.72	.48
Cement										
Cement shed...							44.26			
Labor...	9.00	.01								
Teams...	77.20	.07					4.50			
Total..	86.20	.08	11.80	.01	3 711.53	3.31	48.76	.04	3 858.29	3.44
Concrete Mixing										
Setting up	38.75	.03								
Engineer.	75.50	.07								
Sand.....	37.30	.03								
Stone....	115.65	.11								
Cement..	38.80	.03								
Water and dump...	93.90	.09								
Total..	399.90	.36	49.72	.04	68.44	.06	199.62	.18	717.68	.64
Heating Material.	8.25	.01	1.14				6.00		15.39	.01
Wheeling...	148.35	.13	20.14	.02			14.00	.01	182.49	.16
Placing....	78.90	.07	10.65	.01			24.00	.02	113.55	.10
Water Supply......	82.65	.07	11.42	.01			11.50	.01	105.57	.09
Stage and Forms										
Carpenter	164.75	.15								
Labor....	227.77	.20								
Total..	392.52	.35	53.28	.05	238.54	.21			684.34	.61
Cleaning up	220.55	.20	12.95	.01					233.50	.21
Total concrete....	3 026.22	2.70	380.40	.34	4 128.46	3.68	476.16	.42	8 013.34	7.14

Foundation of Dam.

TABLE 9.

CONCRETE MASONRY DAM BUILT FOR THE AGUA PURA COMPANY, LAS VEGAS, N. M., 1910, 1911.

SUMMARIZED STATEMENT COMPARING COST TO THE CONTRACTOR WITH THE PRICE PAID BY THE WATER COMPANY.

Item.	Cubic Yards.	Cost to Contractor.		Cost to Agua Pura Co.		Contractors' Profit and Loss.			
						Profit.		Loss.	
		Total.	Unit.	Total.	Unit.	Total.	Unit.	Total.	Unit.
Earth excavation Rock excavation	245 790	$1 533.15	$1.50	$1 460.00	$1.43			$73.15	$0.07
Concrete in dam, gatehouse substructure and superstructure	2 720*	19 283.90	7.09	21 318.05†	7.86	$2 034.15	$0.77		
Premium on indemnity policy		246.86						246.86	
Extra work		225.98		259.88		33.90			
		$21 289.89		$23 037.93		$2 068.05 $1 748.04		$320.01	

* 17 cu. yd. has been added to yardage paid for in final estimate to include yardage contained in gatehouse superstructure.

† Includes $1 224.00 extra compensation paid for prosecuting work through cold weather.

Wages: Mexican labor, 15c.; sub-foreman, 17½c.; engineer, 25c.; carpenter, 30c. and 20c.; foreman, 35c.; double teams, 40c.

Materials: *Cement*, $3.02 f. o. b. Hot Springs; rebate on bags, 30c. — figured as 25c. to allow for loss.
Lumber (per M ft. b. m. at mill), $17.00; mill work, $0.60. Cull lumber, $10.00.
Stone, sandstone quarried and crushed at site of work.
Sand, river sand screened and hauled about one-half mile.
Coal, $3.00 per net ton (f. o. b. Hot Springs).

Contractor's Compensation. The above figures of "Cost to Contractors" include an allowance of $400 or $8.00 per day for fifty days' time spent by him at the site of the work.

The hourly rates of wages paid are as shown in the footnote, namely, — Mexican labor, 15¢; subforemen, $17\frac{1}{2}$¢; engineer, 25c; carpenter, 30¢ and 20¢; foreman, 35¢; and double teams, 40¢.

The average cost of materials was as follows: Cement, $3.02, f. o. b. Hot Springs, with rebate on bags amounting to 30¢, which has been figured in these costs at 25¢ to allow for loss, giving net cost of cement $2.77. Lumber, $17.00 per M ft. b. m.; cull lumber, $10.00 per M ft. b. m. at the mill. Mill work, 60¢ per M ft. Stone was quartzite quarried at the site of the work. Sand was secured from the river bed, screened and hauled about 0.5 mile. Coal, bituminous, $3.00 per net ton, f. o. b. Hot Springs.

In figuring the costs, an allowance was made for actual time spent by the contractor upon the work at the rate of $8.00 per day, and included fifty days' time, amounting to $400.

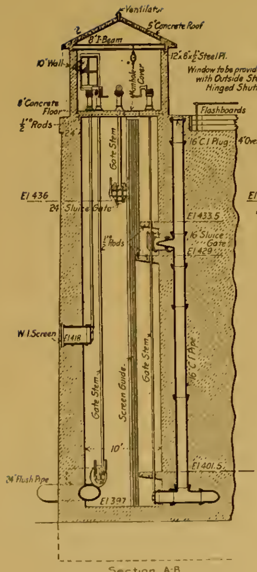
In Table 10 is given a statement of the charges included in the force account, which table indicates the first cost of the machinery, tools and materials, the amount charged to the work and its percentage of the first cost and the estimated value of the several items at the close of the work. From this table it will be seen that an allowance for tools and equipment, amounting to $1 066.20, has been included, which, compared to the first cost of the tools and equipment, amounting to $2 904.90, is equivalent to nearly 37 per cent. of the first cost.

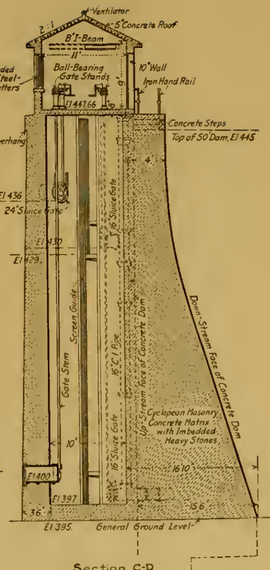
MATERIALS. — CEMENT.

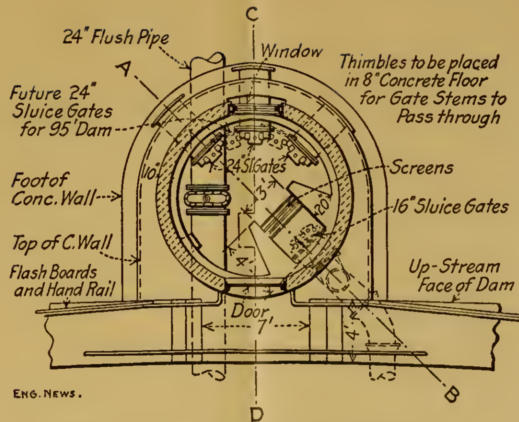
The cement used upon this work was the "El Toro" brand, manufactured by the Southwestern Portland Cement Company at El Paso, Tex., and proved to be a most satisfactory cement. Tests were made in accordance with the specifications of the American Society of Civil Engineers by the George Pierce Testing Laboratory at Portland, Colo., and the cement was purchased a sufficiently long time in advance to enable the securing of a 28-day test.

SAND.

The sand was secured from the bed of the Gallinas River, passed through a $\frac{1}{2}$-in. screen in order to remove occasional gravel, and hauled fully 0.5 mile up two long and steep hills.







Plan of Concrete Gate Chamber,
(Floor Removed.)

PLAN AND SECTION THROUGH
GATE HOUSE OF LAS VEGAS ARCHED DAM.

CRUSHED STONE.

As already described, the stone was of good quality sandstone, and was crushed locally. In order to supply the stone in sufficient quantity to keep the mixing and placing crews busy throughout the day it was necessary to operate the crushing plant in two shifts of ten and twelve hours respectively.

TABLE 10.

STATEMENT OF CHARGES INCLUDED IN FORCE ACCOUNT.

Tools and Equipment.	First Cost.	Amount Charged.	Per Cent. Charged.	Value Remaining.
Cement mixer	$700.00	$350.00	50	$350.00
Stone crusher	1 350.00	337.50	25	1 012.50
Steam pump	57.50	11.50	20	46.00
Boiler	114.70	28.70	25	86.00
Boiler hoods	6.25	1.50	24	4.75
Derricks and ropes	201.08	100.50	50	100.58
Wheelbarrows and small tools	155.62	116.83	75	38.79
Blacksmith tools	30.96	10.06	33	20.90
Wagon — new	85.00	22.10	26	62.90
Sand screens	38.30	16.97	44	21.33
Torches	4.25	2.54	60	1.71
Flue roll and beader	4.00	.80	20	3.20
Steam and water hose	52.00	31.20	60	20.80
Pliers and wrenches	2.02	.60	30	1.42
Old smoke-stack	10.00	9.00	90	1.00
Pipe and fittings	26.97	10.80	40	16.17
Injector	6.75	2.70	40	4.05
Belting (not used)	21.50	1.50	7	20.00
Wagon sheets	38.00	11.40	30	26.60
Totals	$2 904.90	$1 066.20	36.7	$1 838.70
Cement Shed				
Material	145.06	95.06	65	50.00
Labor	25.20	25.20	100	
Repairs	417.23	367.23		50.00*
Totals	$3 492.39	$1 553.69		$1 938.70
Materials				
Cement remaining				120.00
Cement bags returned				785.00
Lumber — cull				50.00
				$2 893.70

* Rebate on pitman.

FORMS.

The forms were made of 2-in. by 8-in. planks, dressed on two edges and one face, and for the lower twenty feet of the structure were braced by means of 2-in. by 6-in. studdings, with numerous 2-in. by 4-in. braces, as shown in Plate XVIII, Fig. 1. For the balance of the structure the forms were made by the use of 3-in.

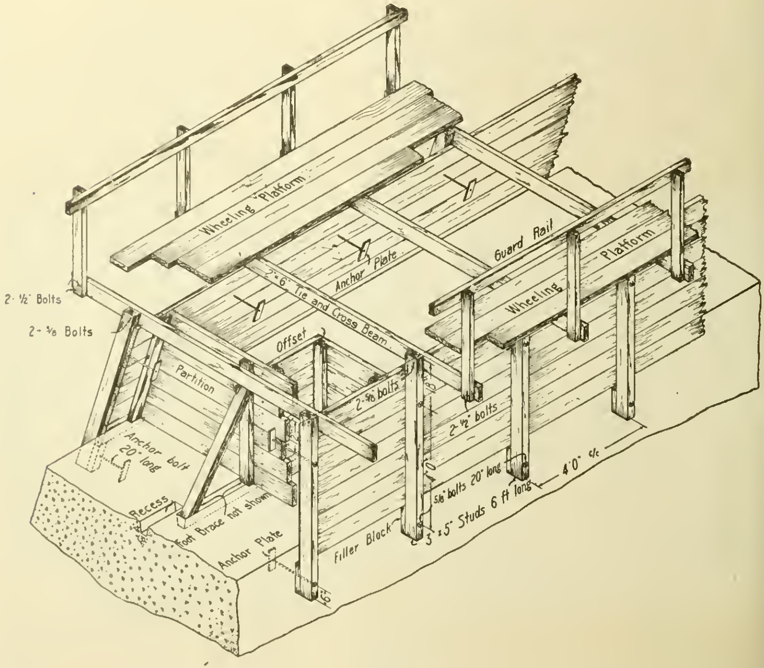


Fig. 17.
Forms for Concrete Dam.

by 5-in. studs, 6 ft. long, with bolt holes placed 4 ft. apart 6 in. from lower end and 18 in. from upper end, so arranged that the $\frac{5}{8}$-in. bolts, 20 in. long, previously set in the wet concrete 12 in. below the surface of the concrete and projecting 8 in. from the face of the dam, would pass through the lower hole of these studdings, which would then be bolted up against a 2-in. wooden

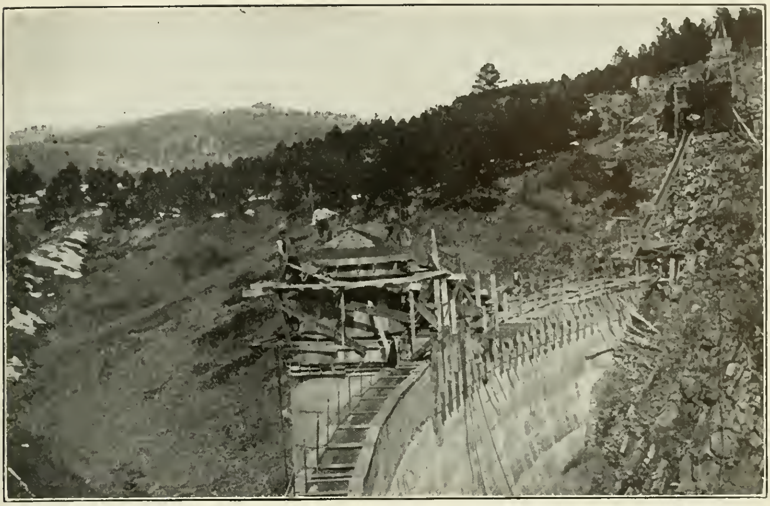


FIG. 1.
TOP OF COMPLETED DAM BEFORE REMOVAL OF FORMS.

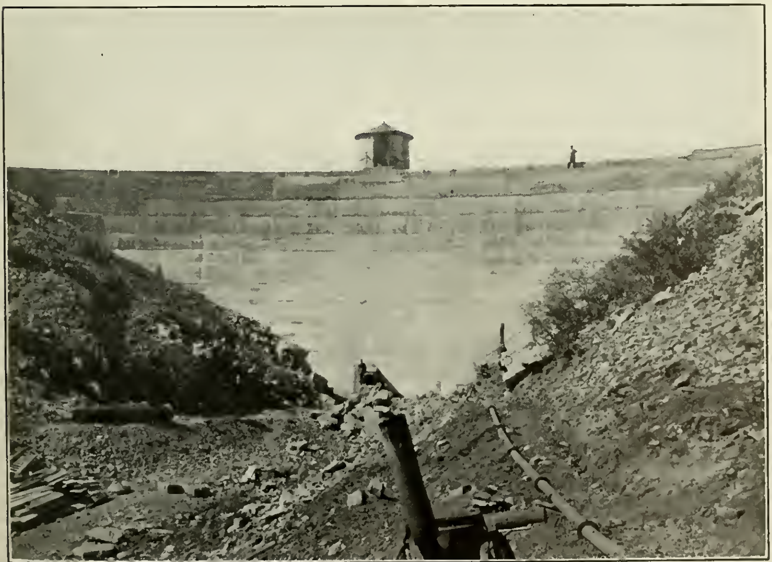


FIG. 2.
DOWNSTREAM FACE OF COMPLETED DAM.

washer which separated the studding from the face of the concrete by the thickness of the forms.

As these studdings were arranged in pairs on either face of the dam on radial lines, it was possible to hold the forms rigidly in place by means of tie-braces across the top, which braces also served to carry the wheeling platforms across the top of the dam, as shown in Plate XVIII, Fig. 2, and Fig. 17. Each time a new block of concrete was placed, new bolts were inserted in the upper holes bored through these studdings, which in turn served as anchorages for the next tier of concrete.

No difficulty was experienced in keeping the forms in line except when the last layer of concrete was placed; in order to bring the dam to the finished crest in one zone, rather than to permit two thin zones to be constructed at the top of the dam where the pressure of ice action must be guarded against, it became necessary to splice these studdings.

HEATING MATERIALS.

As the thermometer in these cañons, during the winter months, frequently drops below freezing during the night and early morning, and sometimes even considerably below zero, whereas during the middle of the day the thermometer is almost always above freezing and frequently remains in the vicinity of 55 degrees and 60 degrees for a greater portion of the day, it was deemed advisable to be prepared to heat the sand and water so that the concrete might be thoroughly warmed when placed. Accordingly, a number of large condemned iron smoke stacks were procured, in which cord wood could be burned while the sand was piled over and around them, by which means it was possible to secure thorough and complete heating. The water was warmed by means of a steam jet constantly blowing into the water tank, and the concrete was covered with canvas, straw, and boards during the night.

We were, however, fortunate enough to experience but little weather in which the temperature was so low as to require the heating of the sand, except on four or five occasions, although it is true there were two periods of several days' duration when the

thermometer went as low as 10 degrees to 20 degrees below zero, but on each of these occasions the work was shut down at the time on account of mechanical defects in the machinery or for other causes.

Cyclopean Masonry.

When the work was contracted it was expected that the Cyclopean form of masonry would be adopted, and with this in view, the contractor erected two small guy derricks, hand operated, which proved to be entirely inadequate for handling the large stones profitably and satisfactorily, with the result that probably not over 200 cu. yd. of stone were thus utilized, and this only in the lower portion of the structure. It is probable that not over 20 per cent. of the first thousand yards of concrete was composed of large stones, or not over 8 per cent. of the entire structure.

When the cyclopean method was used, the stones were placed to break joints horizontally and projecting above the top of the concrete at the end of the day's work, so as to form dentals by which the next course of concrete would be bonded thereto, as shown in Plate XIX. After the cyclopean form was discontinued, the bonding in the horizontal surfaces was secured by imbedding 4-in. by 4-in. timbers, beveled $\frac{1}{2}$ in. on each of the two opposite surfaces, placed lengthwise of the dam in the middle of the surface, which were removed when the surface was cleaned preparatory to the construction of the next course. The vertical joints within a given course were made by means of a three-faced bulkhead, thus securing an offset. of about 2 ft. about midway of this joint.

Before the concrete was placed in the excavation the surfaces of all ledge were thoroughly cleaned of earth, dust, and vegetable matter by means of a stream of water from a hose under pressure, or else by means of steam under high pressure, together with stiff brooms and shovels. In a similar way the surfaces of concrete were cleaned before the succeeding layer of concrete was placed, thus insuring not only the removal of dust, dirt, and chips, but also securing the thawing of any ice which occasionally was found on the surface of the concrete in early morning.

Cliffs along Gallinas River, and Line of Proposed Flume.

Gate Chamber.

The gate chamber was built on the upstream face of the dam, and contained two gates at different levels on supply main, and three gates leading into the reservoir at different levels so as to provide for circulation in the waters of the reservoir. These gates, together with a blow-off gate, were operated from the gate-house floor by means of bevel-geared gate-stands anchored thereto. Provision was also made within the gate-house for two sets of screens for each of the inlet gates, although at the present time but one screen was placed for each gate. The openings for the 24-in. gates leading into the reservoir were protected by means of gratings so as to prevent floating material from flowing into the gate-chamber. See Plate XX.

Completion of the Dam.

With the exception of the construction of the gate-house, the dam was completed February 14, 1911. It contains 2 703 cu. yd. of concrete. The excavation for foundations amounted to 790 cu. yd. of rock and 245 cu. yd. of earth. See Plate XXI.

Gate-House.

The superstructure of the gate-house was built with a small crew of men in three days after the forms were erected. The construction of these forms required the services of one carpenter and five men for a period of three days. The construction of this gate-house was, however, delayed until the early part of the month of March on account of a very severe blizzard during the latter part of February.

Feeder Canal.

Plate XXII indicates some of the difficulties to be encountered in the construction of a high-level canal by which the water is to be delivered to this reservoir from the Gallinas River. The line across the face of the photograph indicates the approximate location of the canal. There are a number of such cliffs along the line selected for the canal, and at each a box flume will be constructed and supported on wrought iron brackets on the face

of the cliff. The flume will be built out gradually from bracket to bracket, the holes for each bracket being drilled from a stage supported as a cantilever from the two brackets next preceding. This affords an inexpensive construction and although it may become damaged from time to time by falling rocks from the overhanging cliffs, it is anticipated that repairs can be easily made.

PAINT FOR STANDPIPES, AND METHODS OF APPLYING.

TOPICAL DISCUSSION.

(*November 13, December 11, 1912.*)

Mr. George A. Stacy.* Mr. President, this is one of the little things pertaining to water works that we are hunting for information on. We depend entirely upon hydrant service, as we have no steamers, so we erected a standpipe, with an independent line of mains and hydrants, for the higher level of the city. As this standpipe is used for fire service only we did not have to be so particular in regard to the paint which was put on the inside, as to its communicating taste or odor to the water. The standpipe was built in 1895, and the specifications called for two coats of the best asphaltum paint that we could hear of at that time. I thought as I looked at it, after it was on, that it would be almost as permanent as enamel and would be a thorough protection to the wrought iron.

In about three years I noticed that it looked as though the paint was all gone. We drew the water off, and even with the microscope you could not detect that there had ever been any paint on the tank in any way, shape or manner, not even in the joints or around the rivets, or anywhere else. I do not know how long the tank had been in that condition, for I had such confidence in the paint that I had never thoroughly examined it. The water was not used for our domestic supply so the fluctuation of water level in the tank was very slight, five feet was the maximum in the winter, when we keep it from freezing by artificial circulation, and one or two feet in the summer.

In repainting we got some paint which was highly recommended,

* Superintendent Water Works, Marlboro, Mass.

some discovery which they claimed made this paint particularly adapted for this kind of work. We had looked around but couldn't find any reliable data which we could go by as to paint that anybody else had used, so we put that on. This did a little better, but at the end of three years was gone. Then we tried something else which had been recently discovered and which had come into use to a certain extent at that time for coating steel pipe. We put that on, and I watched it as time went along, and we found that near the water line, or the ice line, where the ice broke as the water rose and fell in the tank, the ice would break away from the side, and it seemed to affect the paint there more than anywhere else; at the end of three years we emptied the tank to see its condition. We found the paint which was purported to be very elastic and very tough hanging on the sides of the tank in places like loose paper on the wall. There would be a strip attached to the top and hanging loose, and then some few feet off another, and some of it you could pull off. It certainly was tough, but it did not adhere to the iron, so that it was no protection to what was behind it.

I thought, perhaps, that that was due to some imperfection in preparing the tank. I thought the matter over, but I did not see how we could do any better than we had, because the iron was perfectly clean, and there was no question about its being dry, because it was so hot in there when the sun shone that it was very uncomfortable, and when the water was drawn out it didn't take but a little time for the tank to dry, so I laid it to the paint.

This carries us along quite a period, and then we tried a paint which was made of different material. We put that on a few years ago, — I guess it has been painted once since, — and that stayed on about three years and a half or four years, and when we drew the tank off to paint it again it was in the best condition that it ever had been. The paint on the bottom was almost perfect. I thought then we had found what we were seeking, that is, something which had durability and which would last three years and remain effective. So I got the same paint, as I supposed, and applied it again; and in three or four years we drew the tank down and this time it looked a good deal as it did the first time we painted it. I could not detect that there was

any paint left. It was bought from the same party and supposed to be manufactured by the same concern; we paid the same money for it, and I knew that the tank was prepared in the same way as before.

The next time I made a complete shift. I got some red lead, had it ground for me, and painted the inside of the tank with that, and put two coats of other paint outside of it, and in the future, if I live, I will tell you how that comes out.

I am satisfied of this: that up to the present time — and I may be showing considerable ignorance in this matter — I have not yet been able to learn of a paint that will thoroughly protect the inside of a standpipe for a term of three years, so that it will be in good condition at the end of that time. If there is such a paint I should like to know what it is and who makes it.

Of course some of the paint we used would not be put on a tank from which the water was used for domestic purposes. I mentioned what our tank was used for, so you would know that I wasn't hampered in painting it for fear of anything which would cause taste or odor. This is as far as I have got, and I don't think I know a great deal more about it than I did in 1895, when the tank was constructed, and if anybody can give me any information it would be a great favor.

Mr. Frank L. Fuller. I should like to ask Mr. Stacy how many coats of paint he put on.

Mr. Stacy. We put on three, two outside of the red lead.

Mr. Fuller. Will one coat over a coat of red lead cover it, or does it need two coats? For instance, suppose you are putting it on the outside of a tank and have a first coat of red lead, would a second coat of some tint, lead and oil, cover it?

Mr. Stacy. I will say, Mr. Fuller, that that is the reason we put on the third coat. The first coat we put on over the red lead did not thoroughly cover it. On the outside of the tank we haven't had any trouble in finding paint that I consider satisfactory in every way, and would protect the tank thoroughly as long as you would expect anything of that kind to last, say five or six years.

Mr. Fuller. What kind of paint did you use on the outside?

Mr. Stacy. I used a mineral paint, made, I think, by some

people in Cincinnati; I can't tell you just the address now. It was about five years ago that we painted the outside last. We painted it with two tints, — it comes in colors, — and it has given satisfaction. But when we come to the inside of the tank it has been a perfect failure as far as finding anything which was satisfactory.

Mr. Harry L. Thomas. Will Mr. Stacy kindly tell us how he prepared the inside of his standpipe. Did he do anything more than brush it before painting?

Mr. Stacy. It was thoroughly scraped down to the iron. We didn't use any sand blast, but we used chisels, hammers, steel scrapers, and brushes. It was the hardest work to remove the rust around the rivets and around the seams.

Mr. George E. Winslow. I would like to ask Mr. Stacy if he has ever tried pure beeswax for a paint.

Mr. Stacy. No; that is something new. I will try it next time.

Mr. Winslow. I have never used it for painting a standpipe, but I have used it on iron work, on cast iron and on copper and tin, and I have found that it is the best of anything I have been able to get for paint. Perhaps you know that they use it on the iron patterns that are used in foundries, and it keeps the rust off perfectly. Beeswax is not affected by water or, in fact, by any liquid, I don't care what it is. But when you put it on iron you don't want to paint it on and leave it as paint is left. You have to warm the iron and put it on in a very thin coat indeed. In other words, to paint the inside of a standpipe, which I have never done, you would apply it hot with a brush, and then take a blow-torch and warm the iron and let all of it flow off that will. I have found that it works very well on cast iron, and the rust does not attack it.

Mr. Stacy. I will say, Mr. Winslow, that you wouldn't have to use any blow-torch on the sunny side of our tank. The only trouble would be to keep the beeswax from all flowing off down to the bottom.

Mr. Winslow. No; it wouldn't do that.

Mr. Stacy. You can't bear your hand on the tank where the sun strikes it on a bright day.

Mr. Winslow. The beeswax wants to be very thin indeed. You put it on with a brush and put it on hot and as thin as you can, and it will peel even then. But when all has flowed off that can flow off it will leave a coating that will not peel. You put it in a cup, or anything you choose, and let it harden, and you will find a joint between the beeswax and the cup; but by putting it on very thin it works very nicely on my work. I can't say anything about it for use on the outside of a tank, but on the inside, where it is covered with water, there isn't any possibility that it will flake off, if it is put on in the way I suggest. I won't say that it is the thing to use; I merely asked if you had ever tried it; this is only a suggestion.

Mr. Robert S. Weston.* In painting standpipes the metal is fully as important as the paint applied to it. Most of us are pretty well agreed that if we get iron which is free from mill-scale it will stand longer, take the paint better, and the rust beneath the paint will be less apt to push the paint off than if the ordinary metal is used.

Recently I made an experiment with a tank used to hold a ground water containing an excessive amount of carbonic acid. The metal is a new material called "ingot" iron, which is supposed to be a very pure iron made by the steel process. It is practically steel which has been heated in an open-hearth furnace until all the manganese has been burned out of it, or an open-hearth steel treated with heat until it is homogeneous in character. I painted this tank with two coats of a pitch and linseed oil paint and thought that I was going to get conditions which would stand corrosion very well, but after several months' use the water began to corrode the metal and I think I am going to have about the same experience that Mr. Stacy has had.

There is no paint which cannot be criticised, but it is also true that if the mill-scale be removed from plates, paint will stick to the metal very much better. I believe that the modern practice of sand blasting the plates before painting is one of the best steps which has been taken to secure good coatings on the insides of standpipes.

Professor Whipple's experiments at Harvard have shown that

* Consulting Sanitary Engineer, Boston, Mass.

the plates which are most readily attacked by water are those which have the most mill-scale on them, and as long as plates are covered with scale it doesn't seem to make much difference whether the metal is iron, steel, ingot iron, or any other iron alloy, provided the metal is fairly good in quality. When the scale has corroded away, the purer and more homogenous iron is the better, but the advantages of a good steel, free from scale, greatly exceed those of the higher priced, purer iron, with the scale on.

Dr. Cushman, who has done a great deal of work for the Department of Agriculture in getting out specifications for fence wire and other agricultural iron, has advised a paint whose pigment is boiled in potassium bichromate before being ground with the oil. He claims that this treatment of the pigment neutralizes the electrolytic action of the water on the metal. These paints can be procured, I believe, of a Philadelphia manufacturer, but I do not think they have been used long enough to determine how much better they are than the ordinary paints.

Theoretical considerations and experience lead me to believe that the thing to do is to put the paint on clean, dry metal as the first requisite; second, use a paint which contains materials which are elastic and quite insoluble in water. The three types of paint usually used are:

First, pitch or bitumens dissolved in boiled linseed oil;

Second, furnace paints; and

Third, linseed oil paints.

I have tried all of them, but am not in a position to say that any one has the advantage. Pitch paints are a little more liable to contain materials which will dissolve in water. On the other hand, they are the most elastic. Of the pigment paints, those which contain some zinc and a filler like asbestos fiber are a little more durable than those made of pure pigment and pure oil. These latter are liable to disintegrate.

Mr. Dexter Brackett.* Mr. President, I will offer a few notes on the subject, which may be worthy of a place in your records. Our experience on the Metropolitan Water Works indicates that red-lead paint applied to the interior of standpipes

* Chief Engineer, Metropolitan Water Works, Boston, Mass.

is one of the best, if not the best, protection against rusting. The paint now used is mixed in the proportion of three gallons of boiled linseed oil to 100 lb. of the best quality of red lead, to which is added $2\frac{1}{2}$ lb. of litharge thoroughly beaten up with the linseed oil. This is the formula used by the United States Navy for paint used on the bottoms of ships. The litharge causes the paint to dry quickly and also hardens it.

The standpipe on Forbes Hill in Quincy, 30 ft. in diameter and 64 ft. 3 in. high, was painted in 1902 at a cost of $427. The interior was first thoroughly cleaned of rust and loose paint by the use of putty knives and wire brushes. One coat of red lead mixed with raw linseed oil and a little turpentine was then applied, and over this were applied two coats of Gilsonite paint, made by the Commercial Asphalt Company, of New York. The exterior was given two coats of white lead and linseed oil, tinted a light gray color. This standpipe is enclosed in a granite masonry tower and covered so that ice does not form to such an extent as it would if the standpipe were exposed directly to the weather. The interior of the standpipe has not required repainting until the present season. The interior of the standpipe has recently been given three coats of red lead, United States Government specification, with no covering of Gilsonite, and the exterior one coat of white lead and oil, at a total cost of $430.

We have a standpipe in Arlington, 40 ft. in diameter and 60 ft. high, with a conical steel roof and exterior spiral stairway, all exposed to the weather. The water pumped into both this and the Forbes Hill standpipe has a temperature of from 38 to 40 degrees during the winter, and ice forms in this standpipe to a greater extent than in standpipes supplied with water drawn from ground water supplies, which does not ordinarily fall below 50 degrees.

This standpipe was painted in 1906 at a cost of $425. The interior, after being thoroughly cleaned, was given one coat of red lead and two coats of Gilsonite. The roof trusses and under side of the roof were given two coats of red lead and oil, and the exterior of the standpipe and roof one coat of white lead and oil. In 1911 this standpipe was emptied and both exterior and interior repainted in the same manner as in 1906, at a cost of $475.

Mr. C. E. Peirce. I would like to ask the gentleman what preparation he makes for painting.

Mr. Brackett. Thoroughly clean the iron. That is really the best thing which can be done. We have not used sand blasting, but we have thoroughly cleaned the iron by the use of wire brushes and scraping.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, Mass., November 13, 1912.

Mr. George W. Batchelder, the President, presiding.

The following members and guests were present:

Honorary Members.

Desmond FitzGerald, Henry C. Meyer, and Frederic P. Stearns. — 3.

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, G. A. Carpenter, C. E. Chandler, J. C. Chase, R. D. Chase, E. A. Clark, R. C. P. Coggeshall, W. R. Conard, A. W. Cuddeback, J. A. Cushman, E. D. Eldredge, G. F. Evans, F. L. Fuller, A. S. Glover, Clarence Goldsmith, J. M. Goodell, X. H. Goodnough, R. A. Hale, R. K. Hale, F. E. Hall, T. G. Hazard, Jr., D. A. Heffernan, M. F. Hicks, Willard Kent, G. A. Kimball, G. A. King, J. J. Kirkpatrick, C. A. Leary, N A. McMillen, A. E. Martin, F. E. Merrill, Leonard Metcalf, H. A. Miller, J. H. Mendall, William Naylor, G. A. Nelson, F. L. Northrop, H. E. Perry, A. L. Sawyer, J. E. Sheldon, G. H. Snell, G. A. Stacy, W. F. Sullivan, H. A. Symonds, H. L. Thomas, R. J. Thomas, J. L. Tighe, E. J. Titcomb, D. N. Tower, C. H. Tuttle, W. H. Vaughn, R. S. Weston, F. B. Wilkins, F. I. Winslow, and G. E. Winslow. — 65.

Associates.

H. L. Bond & Co., by F. M. Bates; Builders Iron Foundry Company, by A. B. Coulters and G. H. Lewis; Chapman Valve Manufacturing Company, by H. L. DeWolf; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Pittsburg Meter Company, by J. W. Turner; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; Pratt & Cady, by C. E. Pratt; A. P. Smith Manufacturing

Company, by F. L. Northrop; Thomson Meter Company, by S. D. Higley, W. S. Cetti, and E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. K. Otis; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 24.

GUESTS.

F. W. Tucker, W. D. Cashin, Boston, Mass.; J. P. Wood, inspector, Marlboro, Mass.; Frank I. Hamlin, water commissioner, Haverhill, Mass., D. W. Agnew, Scituate, Mass.; Ivers M. Low, superintendent water works; Weymouth, Mass.; and Mr. E. M. Nichols, Philadelphia, Pa. — 7.

The records of the last meeting of the Association were read by the Secretary and adopted.

Applications for membership were submitted by the Secretary from Henry Manley, Jr., Boston, Mass., engaged as assistant in general engineering practice; and Luther W. Burt, Hartford, Conn., active and consulting engineer. On motion of Mr. Frank L. Fuller, the Secretary was empowered to cast one ballot in favor of the applicants, and, he having done so, they were declared elected members of the Association.

Mr. Frederic I. Winslow, engineer of extension, Public Works Department, Water Service, Boston, presented an illustrated paper on "Some Difficulties Encountered in Tunnel and Subway Construction."

Mr. Desmond FitzGerald gave an entertaining description of a trip "From Italy to the China Sea," illustrated by a series of beautiful stereopticon pictures. Before beginning his remarks he expressed his great pleasure at meeting with the members of the Association once more, and finding so many of his old friends in attendance. He was cordially welcomed, and, at the close of his talk, the President on behalf of the members thanked him for the great treat he had given them.

Mr. George A. Stacy opened the topical discussion, the subject being "Paint for Standpipes, and Methods of Applying." The discussion was further participated in by Mr. Frank L. Fuller, Mr. Harry L. Thomas, Mr. George E. Winslow, and Mr. Robert S. Weston.

Adjourned.

December Meeting.

Hotel Brunswick,
Boston, Mass., December 11, 1912.

President George W. Batchelder in the chair.
The following members and guests were present:

Honorary Member.

F. P. Stearns.

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, E. W. Bush, W. L. Butcher, F. H. Carter, J. C. Chase, R. C. P. Coggeshall, W. R. Conard, H. R. Cooper, J. A. Cushman, John Doyle, E. D. Eldredge, T. C. Gleason, A. S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, L. M. Hastings, T. G. Hazard, Jr., J. L. Hyde, Willard Kent, G. A. King, F. A. McInnes, N. A. McMillen, H. V. Macksey, F. A. Marston, A. E. Martin, John Mayo, F. E. Merrill, William Naylor, C. E. Pierce, T. A. Pierce, J. L. Rice, G. A. Sampson, P. R. Sanders, A. L. Sawyer, C. W. Saxe, J. W. Smith, G. H. Snell, W. F. Sullivan, E. S. Tucker, C. H. Tuttle, W. H. Vaughn, F. P. Washburn, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow, I. S. Wood, F. L. Northrop. — 60.

Associates.

Builders Iron Foundry, by A. B. Coulters and G. H. Lewis; Chapman Valve Manufacturing Company, by J. T. Mulgrew; Goulds Manufacturing Company, by R. E. Hall; Hersey Manufacturing Company, by A. S. Glover, J. A. Tilden and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Company, by W. H. Van Winkle, Jr.; Norwood Engineering Company, by C. E. Childs; Pittsburgh Meter Company, by J. W. Turner; Platt Iron Works Company, by F. H. Hayes; Pratt and Cady Company, by C. E. Pratt; Rensselaer Valve Company, by C. L. Brown; A. P. Smith Manufacturing Company, by T. F. Halpin and F. L. Northrop; Standard Cast Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter Company, by E. M. Shedd; R. D. Wood & Co., by H. M Simons; Henry R. Worthington, by Samuel Harrison. — 23.

The records of the November meeting were read by the Secretary and approved.

Applications for active membership, properly endorsed and recommended by the Executive Committee, were presented by the Secretary from Herbert R. Horton, East Providence, R. I., superintendent of Watchemaket Fire District; G. O. House, St. Paul, Minn., general superintendent St. Paul Water Department; Alvin C. Howes, Middleboro, Mass., superintendent Middleboro Water Works; D. McD. Campbell, Sydney, N. S., city engineer of Sydney.

On motion of Mr. Thomas A. Pierce, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared duly elected members of the Association.

Mr. Gilbert H. Pratt, chemist of the Rhode Island State Board of Health, read a paper entitled "Uses and Abuses of Water Filtration." Mr. Charles W. Saxe spoke briefly in regard to the filtration plant at Newport, R. I.

Mr. William T. Barnes, civil engineer, Chicago, Ill., gave a description of the Las Vegas dam, illustrated by stereopticon views.

The subject of "Paint for Standpipes, and Methods of Applying," which was discussed at the November meeting, was again taken up and discussed by Mr. Dexter Brackett.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, November 13, 1912, at 11.30 A.M.

Present: President George W. Batchelder, and members Millard F. Hicks, Robert Spurr Weston, George A. Stacy, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Two applications for membership were received and recommended for admission, namely: Henry Manley, Jr., civil engineer,

Boston, Mass.; and Luther W. Burt, civil engineer, Hartford, Conn.

It was *voted:* That three former members of the Association, dropped for non-payment of dues on June 10, 1912, having since said date remitted their dues, be, and they are hereby, restored to membership in the Association.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 11, 1912, at 11.30 A.M.

Present, President George W. Batchelder and members J. Waldo Smith, Robert Spurr Weston, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Four applications were received and recommended for membership, namely:

For members: Herbert R. Horton, superintendent Watchemaket Fire District, East Providence, R. I.; G. O. House, general superintendent St. Paul Water Department, St. Paul, Minn.; Alvin C. Howes, superintendent Middleboro Water Works, Middleboro, Mass.; D. McD. Campbell, city engineer, Sydney, N. S.

One former member, dropped from the rolls for non-payment of dues, having paid same in full, was by vote reinstated.

Adjourned.

Willard Kent, *Secretary.*

OBITUARY.

George Albert Kimball.
Died December 3, 1912.

George Albert Kimball was born in Littleton, Mass., May 14, 1850, the son of William and Mary (Lawrence) Kimball. He received his early education in the schools of Littleton and, later, at Appleton Academy, New Ipswich, N. H., where he prepared for Dartmouth College. Owing, however, to serious trouble with his eyes he was obliged to give up his college course.

In 1869 he took up the study of civil engineering in the office of Frost Brothers, of which firm he later became a partner, where he remained until 1874, when he opened an office in Somerville. From 1876 to 1887 he was city engineer of Somerville. During that time he was also chairman of the city board of health, an alderman, and member of the water board. In 1887 he opened an office in Boston for the practice of engineering. In 1888 he was appointed a member of the Grade Crossing Commission, and in 1896 a member of the Metropolitan Sewerage Commission. In 1896 he was made chief engineer of the Boston Elevated Railway Company, in which capacity he was responsible for the design and construction of all the elevated and subway work. Mr. Kimball during these years made a specialty of the construction of sewers and water works and had collected a valuable library on these subjects covering many New England cities and towns.

In 1872 Mr. Kimball married Elizabeth Emily Robbins, of New Ipswich, N. H., who with four children survives him. He died of heart failure at his home in Arlington, December 3, 1912.

Mr. Kimball was a director of the American Society of Civil Engineers, a past president of the Boston Society of Civil Engineers, a member of the Institute of Civil Engineers and of the American Institute of Consulting Engineers. He was also a member of many clubs and fraternal orders. He was elected a member of the New England Water Works Association on June 17, 1887.

BOOK REVIEW.

A TREATISE ON HYDRAULICS. By Mansfield Merriman. Ninth edition, revised and reset, with the assistance of Thaddeus Merriman. 8vo, x+565 pages, 224 figures. New York: John Wiley & Sons. Cloth, $4.00 net.

This book is so well known to all students of hydraulics that an extended review is unnecessary. The first edition was published in 1889 and it has been reprinted and enlarged many times since. In 1903 it was rewritten and enlarged (eighth edition), and many new features were added to it when reprinted. The present edition (ninth) has been entirely revised and reset in order to present more logically the previous additions and to include more fully the advances of the last decade. The chief additions are chapters on hydraulic instruments and observations, and pumps and pumping, but much new material has been added to other chapters. As in previous editions many of the formulæ and tables are repeated with metric units, and an interesting but brief history of hydraulics is included.

Although primarily intended for the use of students in technical schools, it is an excellent reference book for practicing engineers, and will be of great value to any one who has to solve hydraulic problems; but the writer noticed few of the tables and none of the diagrams so useful for the solution of everyday problems in the office.

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J. WALDO SMITH,

President New England Water Works Association,

1913.

New England Water Works Association.

ORGANIZED 1882.

Vol. XXVII. March, 1913. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE LOWELL WATER WORKS AND SOME RECENT IMPROVEMENTS.

BY ROBERT J. THOMAS, SUPERINTENDENT OF WATER WORKS, LOWELL, MASS.

[*Read January 8, 1913.*]

Some improvements recently made in the water works of the city of Lowell, including an extension of the driven well system and the construction of a new pumping station and distributing reservoir, are to serve as an excuse for the presentation of this paper for your consideration.

It is proposed, however, as a preliminary to the description of these improvements, to review the development of the water system to date, in the belief that the experience of a city of more than 100 000 people in obtaining a supply from an underground source may be of general interest.

The installation of water works was discussed as early as 1838, but nothing was done until 1870, when, after a report by Mr. J. Herbert Shedd, and another by Mr. Joseph P. Davis, construction was begun, following the recommendations of the latter engineer, who advised filtration of the Merrimac River water, with preliminary sedimentation. The water was to be taken from the north side of the river at a point a short distance above the Pawtucket dam, and carried through an oval brick conduit with a capacity of 9 000 000 gal. per day, to settling basins of twenty-four-hour capacity and filters located near the outlet of Beaver Brook. From the filters the water was to flow through a second brick

conduit 4 ft. 6 in. in diameter, passing under Beaver Brook in a cast-iron inverted siphon, and terminating in a clear water well 100 ft. square and 10 ft. deep, at a pumping station in Centralville. From the pumping station the water was to be pumped to an open distributing reservoir of 30 000 000 gal. capacity, with high water at elevation 181.5, located on Beacon Hill. The datum of all elevations herein referred to is 47.28 ft. above mean low water at Boston.

Work was begun in July, 1870, but for some reason the scheme of the engineer was materially changed, the settling basins and filter beds being abandoned and a filter gallery 8 ft. square in section and with its bottom 8 ft. below the crest of the Pawtucket dam was substituted, these changes being, in the first place, the result of a belief in the minds of the city authorities that the river water was safe without filtration, and also because investigation apparently indicated the possibility of obtaining a sufficient supply of ground water from the gravel deposits along the river bank.

As constructed, the work consisted of the filter gallery 1 300 ft. long, about 100 ft. from the shore line of the river, a brick conduit 4 ft. 3 in. in diameter, 4 183 ft. long, and 6 656 ft. of 30-in. pipe ending in the pump well at the Centralville station. A 30-in. pipe 220 ft. long, controlled by gate valve, was also laid from the filter gallery to the river, with the idea that, should the gallery prove insufficient at low stages, the deficiency might be made up by direct draft from the river.

The distributing reservoir was uncovered and was constructed from the material excavated, with earth embankments 15 ft. wide on top and $1\frac{1}{2}:1$ slopes on the inside and $2:1$ slopes on the outside. The inside slopes were lined with clay puddle 2.5 ft. thick and paved with granite blocks 15 in. thick, underlaid with 10 in. of broken stone. The bottom was covered by one foot of puddle, but not paved. In 1886, when the water was drawn off for the purpose of cleaning, the interior slope started to slide, necessitating reinforcement, and as a result the reservoir has not since been emptied. The force main, which leads directly from the pumps without connection with the distribution system, extends to the back of the reservoir, insuring circulation and a storage period which has averaged about five days.

It had been estimated that the filter gallery would yield 2 500 000 gal. per day, but in 1875 only 900 000 gal. per day could be obtained, and as the daily consumption had reached 1 220 000 gal., the balance was taken direct from the river. To prevent the use of this raw water, a sand filter bed, well underdrained and composed of 36 in. of gravel and 48 in. of sand, having an area of 11 400 sq. ft., and the surface of the sand one foot below the crest of the Pawtucket dam, was constructed in 1876 on the bank of the river. Water was admitted from the river through a 12-in. pipe, and the underdrains were connected with the filter gallery by a 30-in. pipe.

With the growth of the city in the higher districts, it became necessary to develop greater pressure in certain areas, and accordingly the distribution system was divided, and in 1881 a high service reservoir with flow line at elevation 253.5 was constructed. This reservoir is uncovered, 150 ft. by 130 ft. in horizontal dimensions, and 17 ft. deep, and has a capacity of 1 300 000 gal. The embankments of earth obtained from the excavation are 17 ft. wide on top, with slopes of $1\frac{1}{2}:1$ on the inside and $2:1$ on the outside. A lining of puddle 2 ft. thick on the slopes and one foot thick on the bottom was provided, and the slopes are paved with granite blocks 12 to 15 in. thick, underlaid with 10 in. of broken stone. To supply this reservoir, an independent pump and 12-in. force main were provided.

The filter bed, because of rapid silting up of the surface, did not prove as effective in meeting the requirements of the city as anticipated, and after 1879, when the consumption had reached 2 000 000 gal. per day, an amount of raw water, which gradually increased from year to year, was drawn from the river. During this time, typhoid became prevalent and in 1890–91 serious epidemics in Lowell and Lawrence forced an effort to obtain a better supply. Search for ground water was made by driving test wells along the bank of the river above the filter gallery, and near Beaver Brook, but without success. Better results were, however, obtained in the valley of River Meadow Brook, south of the city, and here water in large quantity, and of apparently good quality, was found. In 1893 a contract was accordingly made with the Cook Well Company, whereby this company was to drive wells

and lay the suction pipes necessary to furnish a supply of 5 000 000 gal. per day for the sum of $24 250. Forty-five 6-in. wells provided with Cook strainers of variable length, depending on the depth of water-bearing stratum, were sunk by sand bucket to depths varying from 47 to 67 ft. All joints were flanged, and each well was separately gated from the suction main. These wells at first yielded 7 000 000 gal. per day, but the supply quickly fell to 2 000 000 gal. per day. As a result, fifteen 4-in. wells were driven and the supply increased to 3 000 000 gal., but after sixteen months' test, the contractor concluded that the original guarantee of 5 000 000 gal. daily could not be fulfilled and abandoned his contract. In 1893, 28 per cent. of the water used by the city was furnished by the Cook wells. Believing, however, that a greater supply could be obtained from the valley of River Meadow Brook, the city in 1894 entered into a contract with the Hydraulic Construction Company of New York to provide an additional plant, located so as not to interfere with the Cook wells, which should deliver not less than 2 000 000 gal. daily, for the sum of $19 749 per million gallons, including wells, pipe system, pumping machinery, and accessory apparatus. It was stipulated that not more than 3 000 000 gal. daily should be paid for in any event.

The contractor drove one hundred and twenty 2-in. wells and obtained, without apparently reaching the limit of the supply, 3 000 000 gal. per day. These wells, sunk by wash pipe, and averaging about 45 ft. deep, were located about a mile upstream from the Cook wells, two thirds of the total number being driven in two lines 12 ft. apart, parallel to the old canal and 200 ft. southwest of it, the wells being 25 ft. apart in the lines. The remaining wells are located in two similar parallel lines, extending at right angles from the center of the other lines. Subsequently additional wells were added to the Cook system, making the total in this plant fifty 6-in. wells and forty of smaller sizes, but the total yield of all wells in the valley of River Meadow Brook proved somewhat less than 5 000 000 gal., and as the daily consumption in 1895 had risen to about 7 000 000 gal. it was still necessary to draw water from the river, 34 per cent. of the total supply being so obtained in this year.

It is interesting to note that the watershed of River Meadow Brook has an area of about ten square miles, and that some sections of the valley are covered by deposits of peat and vegetable muck.

In 1895 the State Board of Health concluded that not more than one half of the water required could be obtained from this source during the dry season, stating also that the supply had grown harder and the color, ammonias, and iron had increased with continued use, and advising that the city proceed to obtain a supply of pure water from some adequate source, or filter the Merrimac River.

In 1895, after an investigation of the Groton ponds and Salmon Brook had proved the infeasibility of these sources, the city authorities decided on a further development of an underground supply, — locating the wells between the Pawtucket Boulevard and the Merrimac River, about two miles above the dam in land which had already been given to the city for park purposes.

In July, 1895, a contract was made with B. F. Smith & Co., whereby this company was to deliver 2 000 000 gal. per day for the sum of $13 461.70 per million gallons, demonstrated to be available by the contractor for one year, this price to cover wells and piping, but the contractor to provide the pumping plant, which the city reserved the right to purchase at 75 per cent. of its cost. A first line of 60 wells was driven 34 ft. from the south side of the boulevard, and parallel thereto, yielding 800 000 gal. per day. Another line of 66 wells was then driven parallel to the first, and 280 ft. nearer the river, averaging 25 gal. per minute per well, but so much ammonia and iron developed in the water that this line was pulled up and abandoned. A line of 22 wells running north and south, and another line of 122 wells parallel to the river, but 110 ft. further away from the river than the abandoned line, were then driven, — the final outcome being 169 effective wells, which yielded about 4 000 000 gal. daily. The city purchased the plant from the contractor for $45 000, including wells and pumping equipment.

The wells just described vary in depth from 27 to 40 ft. and are located at a distance of 150 to 350 ft. from the bank of the river. The suction main ranges from 10 to 24 in. in diameter, and ends

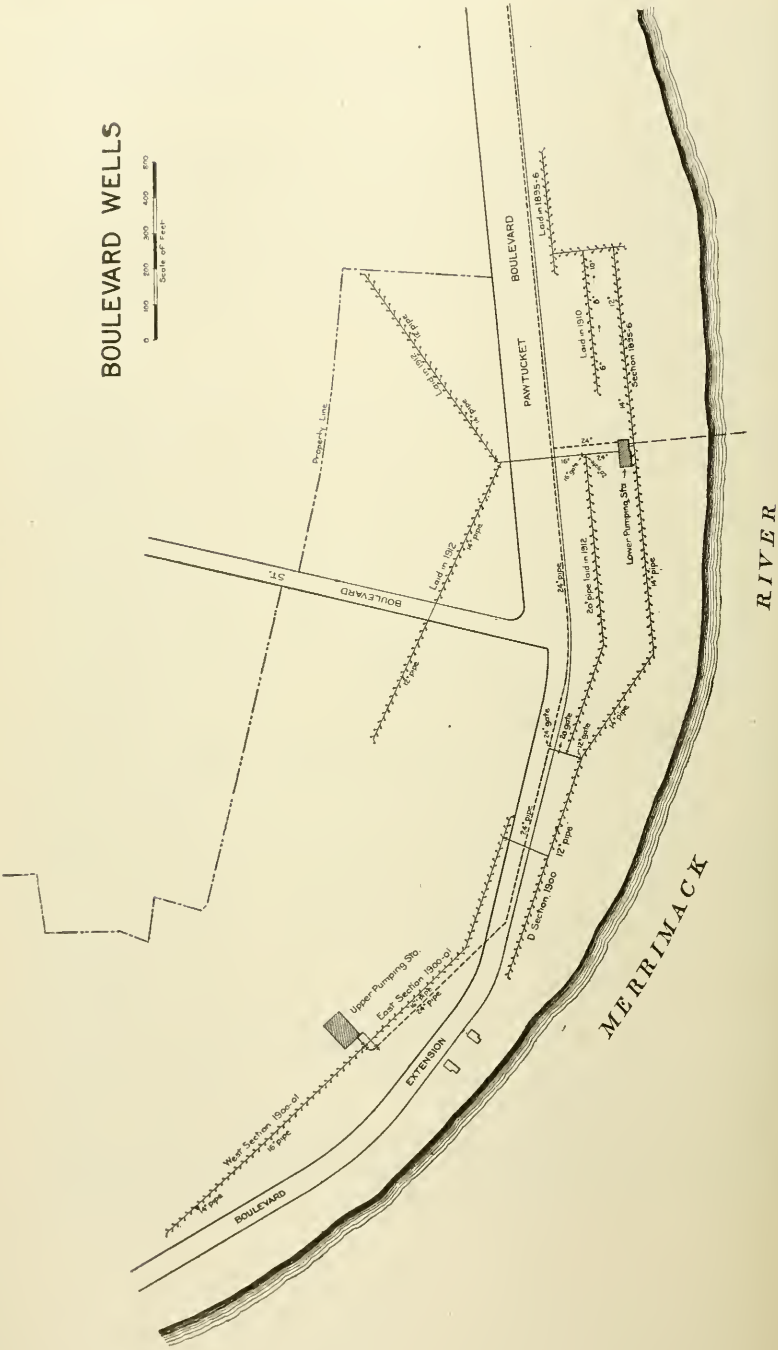
BOULEVARD WELLS
0 100 200 300 400 500
Scale of Feet
PAWTUCKET
BOULEVARD
Laid in 1895-6
Laid in 1910
Section 1895-6
Lower Pumping Sta.
14" pipe
20" pipe laid in 1912
24" pipe
Laid in 1912
12" pipe
14" pipe
Property Line
BOULEVARD ST.
24" gate
20" gate
12" gate
D Section 1900
12" pipe
24" pipe
Upper Pumping Sta.
East Section 1900-01
24" pipe
West Section 1900-01
16" pipe
14" pipe
BOULEVARD
EXTENSION
MERRIMACK
RIVER

Fig. 1.

in a receiver 6 ft. in diameter and 11 ft. long, from which air is withdrawn by vacuum pumps through a riser pipe connected to the top of the receiver.

A low pressure 24-in. cast-iron force main, 9 600 ft. long, leads from the pumps to the old filter gallery, and thence flows to the Centralville station, where it is pumped into the distributing reservoir.

After February, 1896, the Boulevard and River Meadow wells furnished a supply sufficient in quantity for the needs of the city without resort to the river, but soon the quality of the latter supply became a live issue. In 1897 complaints of tastes and odors, chargeable to the exposure of the ground water to light in the open reservoirs, were frequent, and the advisability of a covered standpipe was considered, but nothing was done.

After an investigation of the action of water upon lead, made during the preceding year, the State Board of Health in 1899 called the attention of the city authorities to the effect of the ground water — particularly that from the valley of River Meadow Brook — on lead service pipes, and to the danger existing from continuing to supply consumers with this water, impregnated with an accumulative poison. The corrosive action was attributed to the excessive carbonic acid in the Cook well water, which was found to be greater in amount than in any other supply in the state. The lead in this water during the hours of ordinary use was reported to average .41 parts per 100 000, or eight times the amount generally regarded as the danger limit. The carbonic acid in the Cook well water averaged about 3.95 parts per 100 000; the dissolved oxygen, 10.2 per cent. of saturation; while the corresponding figures for the water from the Boulevard wells were 1.84 per 100 000 and 15.8 per cent. Many severe cases of lead poisoning were reported, and the State Board of Health recommended either the replacement of all lead services or the abandonment of the River Meadow Brook wells and the extension of the Boulevard system.

Accordingly, 52 additional wells were driven in 1900, and connected to the Lower Boulevard pumping station, while in 1901 125 wells were added and a new station, known as the Upper Boulevard station, was constructed. This latter plant is about

1 900 ft. northwesterly of the lower station, and is connected therewith by a 24-in. main, which can be used either as a force main for the upper plant or a suction pipe from the upper wells to the lower station.

During 1902 and 1903, no water was drawn from the Cook wells, but the decrease in the supply obtainable from the Boulevard system made it necessary to use this water in amounts varying from 3.2 per cent. of the total consumption in 1904 to 19.4 per cent. of the total in 1911.

Coincident with the reduction in capacity of the Boulevard system, a gradual deterioration in quality, indicated by increasing ammonias and iron, with the attendant organism Crenothrix, occurred, giving rise to many complaints, and evident physically by the increased color and turbidity of the water.

In 1911 this reduction in capacity and depreciation in quality had so far progressed that some action became necessary. Accordingly, 118 more wells were driven, 53 in a line west of the lower station and south of the Boulevard, and the remainder in two radial lines, starting from a common point on the north side of the Boulevard. About 450 wells in all are now available for use in this field.

As in the other wells at this location, $2\frac{1}{2}$-in. extra heavy iron pipe was used, with a bottom section 38 in. long, perforated by one hundred and eighty $\frac{1}{2}$-in. holes, and having a spiral groove with a pitch of 1 in. cut into it, in which a brass wire is soldered for the purpose of maintaining a space of $\frac{1}{8}$ in. between the gage and pipe. The cast-iron well point into which the bottom section is screwed has a diameter of $4\frac{1}{8}$ in. and serves to make a larger hole than the well pipe, and so protect the strainer during driving. The strainer is of brass, perforated by longitudinal slots, there being twenty slots per inch horizontally and six per inch vertically.

The wells are driven by heavy drop hammer; a wash pipe is not used.

Each well pipe extends to the surface of the ground, where it is capped, a tee being inserted at the elevation of the suction main, to which it is connected by $2\frac{1}{2}$-in. iron pipe, a flanged end gate valve being inserted to enable each well to be cut off, and the connection with main being a screwed joint in a boss cast on the

FIG. 1.
CLEANING DRIVEN WELLS AT LOWER BOULEVARD PUMPING STATION.

FIG. 2.
PUMPING STATION.

latter pipe at an angle of 45 degrees. The wells are staggered 12 ft. apart on either side of the suction main, and 4 ft. therefrom, the main being laid with a grade rising to the air chamber, and at a depth sufficient to keep it below frost.

The material in which the wells are driven is relatively fine, so fine that the ordinary open end well cannot be used, and such that a strainer to keep out the smallest particles of sand is necessary. As a result, these strainers naturally clog, and as is found when the well pipes are pulled up, the space between the gauze and the pipe is filled with a sediment composed of the finest sand and compounds of ferrous iron and organic matter. A similar deposition, presumably, also takes place in the surrounding soil, but lessening in degree with increasing distance from the well.

On several occasions investigation has shown certain wells to yield no water because of the clogging just described, and these were pulled up and new wells redriven in a new location. Frequently, also, the entire system has been cleaned by shutting off the individual wells, removing the cap, and working up and down a wire bristle brush until the interior was clean, and alternately pumping and pouring in water until the supply came clear (Plate I, Fig. 1). In 1909 the most which could be drawn from the wells in March, after cleaning, was 5 000 000 gal. per day, but in April, after a four days' shut-down, 6 000 000 gal. could be easily drafted, indicating a capacity for recovery by rest which is of considerable interest.

A large percentage of the water undoubtedly comes from the adjacent river, and as the character of the underlying sands varies in porosity, the velocity of the subsurface flow and the purifying action is not uniform in all sections, and the quality of the water drawn from different wells, as a result, differs greatly. That the water, in great part, comes from the river, is evident by the seasonal changes in temperature, which are more pronounced than in a true ground water supply, and range between 45 degrees in winter and 65 degrees in summer.

The Merrimac River contains a considerable amount of organic matter, and this water, while purified to a degree where it is bacterially safe, is not filtered under the conditions necessary for complete chemical purification. Passing at varying velocities

through sands of different character, as already stated, there are sections where the rate of filtration is so high that the oxygen available in the water or soil is not sufficient to oxidize the organic matter originally in the water or taken up in passing through the river bed, and as a result, the iron oxides existing in the sand deposits are robbed of their oxygen and reduced to soluble form. That the quality of the water varies greatly in different parts of the field is known by examination of the supply for individual wells, and in 1909, 68 of the old wells were shut off because of excessive iron.

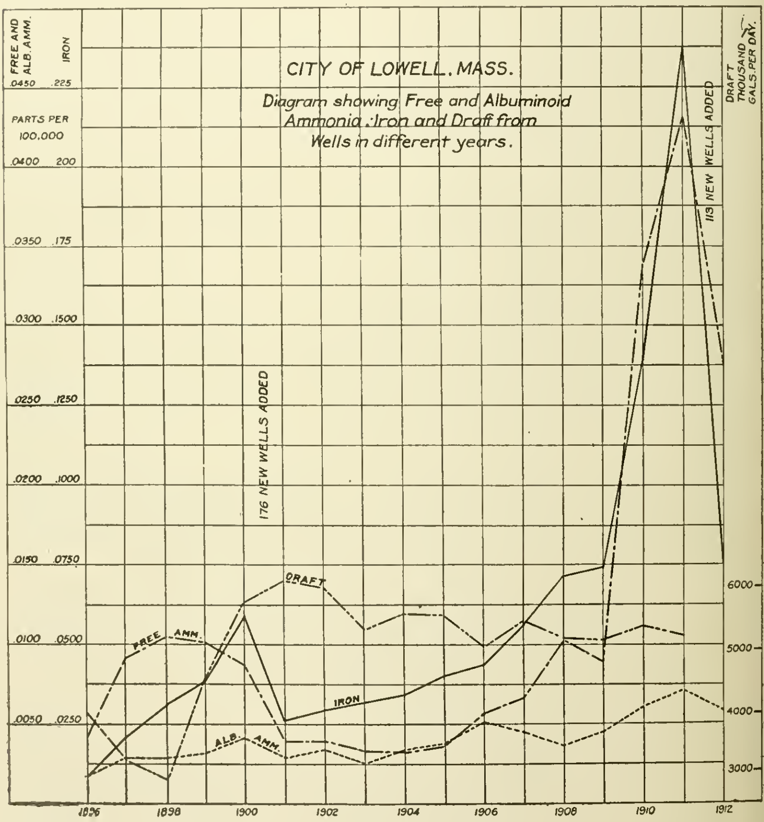

FIG. 2.

Iron in solution will always result when the oxygen originally in the water or made available during the process of filtration is not sufficient to oxidize the organic matter in the water or that which has gradually accumulated in the filtering medium. Increased distance between the stream and the well furnishes assurance of greater uniformity of rate in different sections, and a more complete purification, but the latter only if, by the increased distance, additional oxygen is made available. It is only by keeping the rate of filtration so low that the available oxygen will be sufficient to purify the organic matter that deterioration of the supply can be prevented, and this deterioration, as is proved by experience at Lowell, is progressive with prolonged use, and without material increase in the rate at which the water is drawn through the ground.

The diagram (Fig. 2) showing the amount of ammonias and iron in relation to the daily draft indicates this progressive deterioration in quality. From 1896 to 1900, the iron increased from .0098 parts per 100 000 to .0591 parts, but with the addition of 177 new wells, in 1900–1901, it dropped back to 0.0260 parts. From this figure it gradually rose to .2379 in 1911, but fell to .0793 as an average for 1912, partly because of the 118 additional wells placed in service during that year. In the first month of using these new wells, the iron was as low as .0020, but after four months' service it has risen to .0350. That these conditions are not due to increasing draft is proved by reference to the curve of consumption (Fig. 3), indicating the present use to be 10 per cent. less than the consumption of ten years ago, although the population has in the meantime increased about 10 per cent. At the present time the consumption is approximately 50 gal. per capita, the reduction having been due to the extension of the meter system.

It is to be noted, however, that the consumption in the maximum month sometimes rises to 30 per cent. in excess of the average for the year, and that this increase, coming as it usually does at the time when the supply is at the lowest point, is a more important factor where the water is drawn from the ground than in the case of a surface supply with large storage in reserve. It should also be noted, in considering the quality of the supply during recent

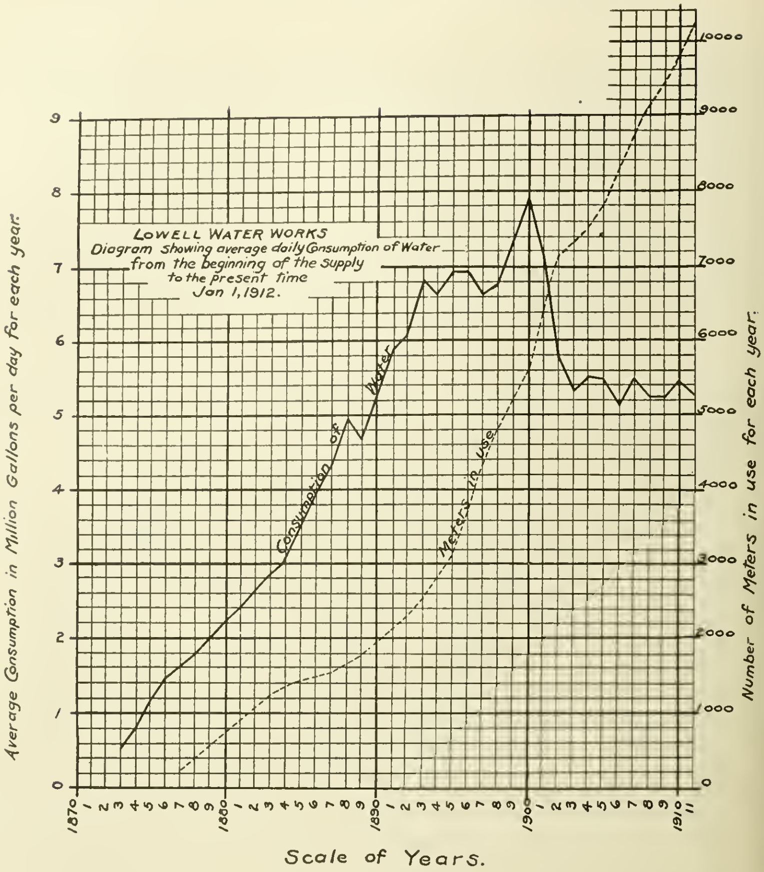

Fig. 3.

years, that the rainfall and run-off in these years has been much below the average, as is indicated by the following figures.

Year.	Per Cent. of Average.	
	Rainfall.	Flow of Merrimac River.
1908	83	75
1909	93	65
1910	79	68
1911	90	61

Coincident with the development of iron in the well water, the fungus Crenothrix has been unpleasantly in evidence. It is found in the wells, conduit, pump well, and distribution system, imparting color, taste, and odor to the water, particularly where stagnant in dead ends, and causing stoppage in house connections when dislodged by any marked change in velocity of flow through the pipe system.

It is obvious that the iron is the undesirable factor in the present supply, and it is equally obvious that the remedy, if this supply from the ground is to be continued, is either to so extend the well system that the rate of draft from the river per unit of filtering area will be sufficiently low that the available oxygen will effect purification, or else to aërate and filter the ground water at high rates before supplying it to the consumer. In regard to the latter possibility, it is to be noted that because of the fineness of the sand and the fact that only in certain sections are the subsurface conditions suitable for driven wells, there may be some question as to the ultimate quantity which can permanently be drawn from the area adjacent to the river.

Another possibility of bettering the quality and increasing the quantity of water obtainable from the present well system is the intermittent pumping of the river water in small quantities on areas suitably prepared adjacent to the wells, and, by slow percolation through the sand lying between the surface and the well point, effecting purification, as is done in a number of places in this state. Should this not prove feasible, because of the difficulties of winter management, the final result at some time in the future may be the filtration of Merrimac River water. Without much doubt, the Lowell supply has been obtained up to the present time at less cost than would have been possible by filtration of the river water, and perhaps a further development of the present system may meet future requirements, but it is obvious that before long something must be done to better the quality of the supply. In any event, whatever the final method adopted, the pumping station just constructed will serve a good purpose, as the supply will be obtained from the same location, and the new covered reservoir will be equally as necessary as under present conditions.

The old station at the Lower Boulevard plant was a wooden

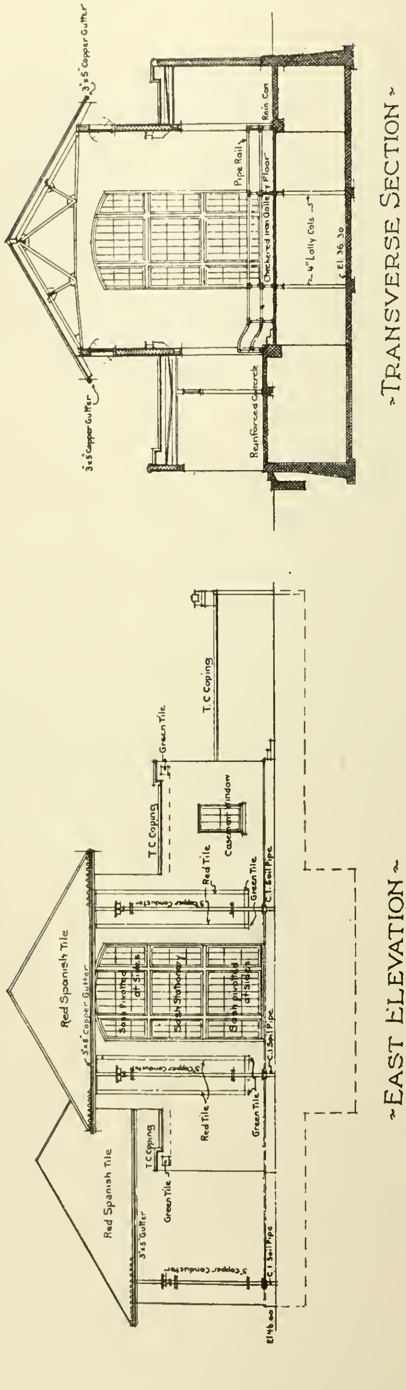

Fig. 4.
Pumping Station.

structure, involving considerable fire risk in the housing of the machinery on which the supply was largely dependent. In 1908 an 8 000 000 gal. Holly, vertical, triple-expansion engine had been put in service, and as by test duty the engine had developed 120 000 000 ft.-lb. per 1 000 lb. dry steam, and was yearly saving in fuel $8 000 over the cost of operating the apparatus previously in use, or sufficient to return its cost in less than four years, practically all of the pumping was being done with this more economical engine,

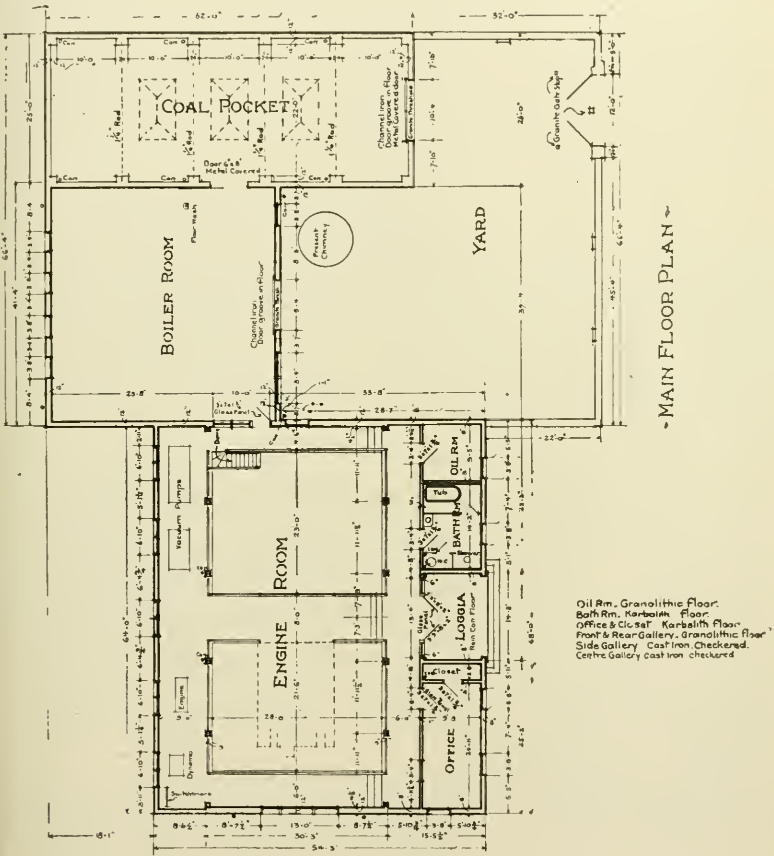

Fig. 5.

Lowell Water Works Pumping Station.

and it appeared advisable to provide a better building for its housing.

The new station (Plate I, Fig. 2), which has just been completed, is of hollow tile, plastered inside and outside with cement mortar, white quartz sand being used in the outer coat. The building, which includes an engine room, boiler room, and coal shed, is plain in design, but, with its white walls and red tile roof, is believed to be well adapted to its location on the Boulevard, with the river for a background. A wall encloses a yard and serves to tie together a rather disjointed ground plan, due to the necessity of adapting the layout to the old wooden station, over which the present building was erected. In order that the Holly pump might be kept in operation, the walls and roof of the new station were constructed before the dismantling of the old station began. The contract also included the resetting of the boilers, which were moved to a new location, and the tearing down of several old engine foundations. The contract price was $22 494, of which probably $2 500 is chargeable to dismantling of old work, making the net cost of the new building about $20 000, or 14 cents per cubic foot of volume. A feature of the building is the cross section of engine room, with a short span for the main portion, and with alcove projections for office, bathroom, oil room, and small auxiliary machinery.

The construction of the new reservoir was undertaken with the object of raising the pressure in the distribution system, and also to provide for storage of the ground water without exposure to light, and so prevent the growth of organisms giving rise to tastes and odors. In 1911, the old Morris pumping engine having become expensive to operate, an Allis Chalmers 8 000 000 gal. vertical, triple-expansion engine was put in service at the Centralville pumping station, and adapted to the pumping of water to the greater pressure which would result from the development of storage at a higher elevation.

The reservoir, which has recently been completed, was located near the open reservoir on a lot already owned by the city, in order to save the expense of acquiring additional land. Its water line at elevation 211.5 was made as high as possible within the limits of this land, and at the same time balance excavation and embank-

Plate II.
N. E. W. W. Association.
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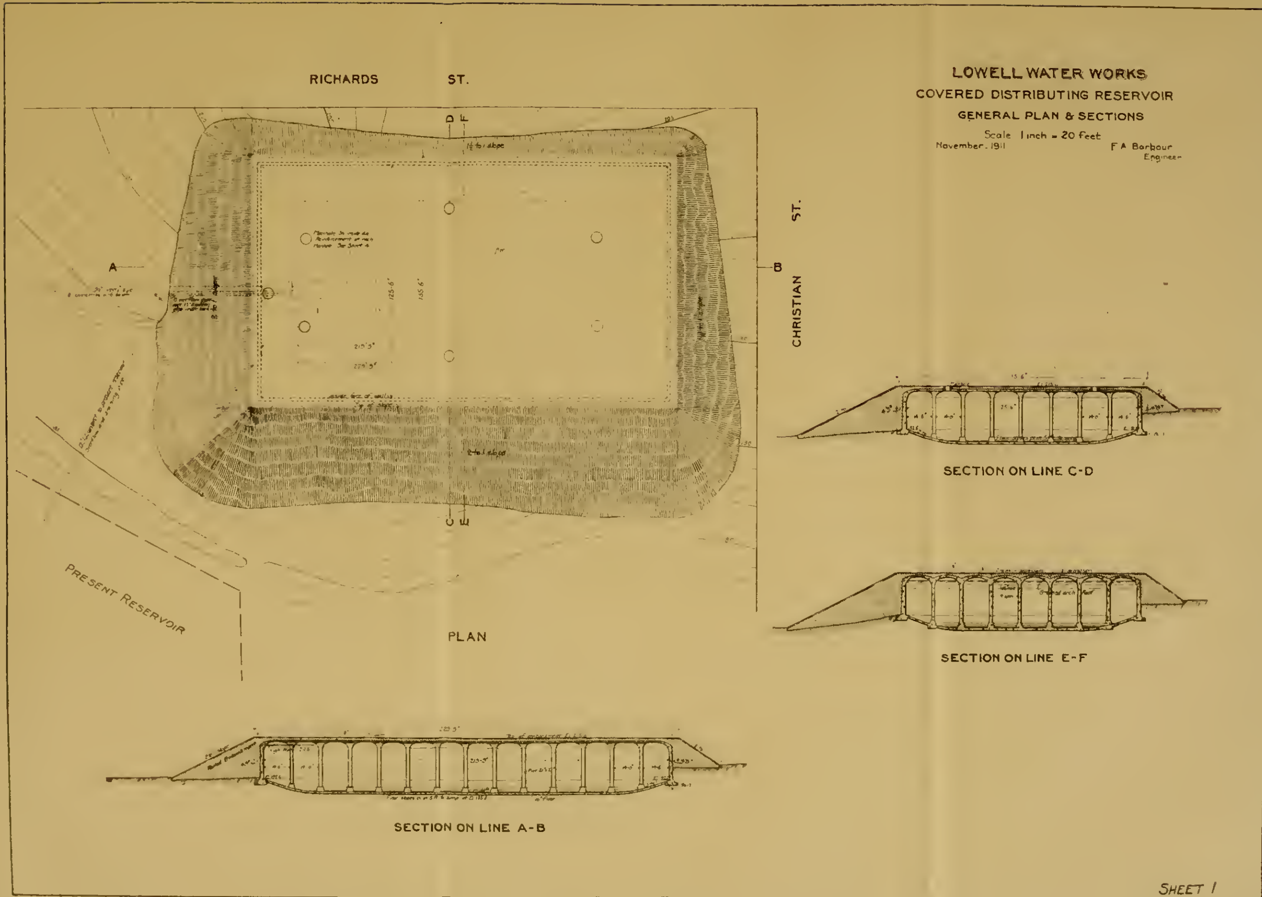
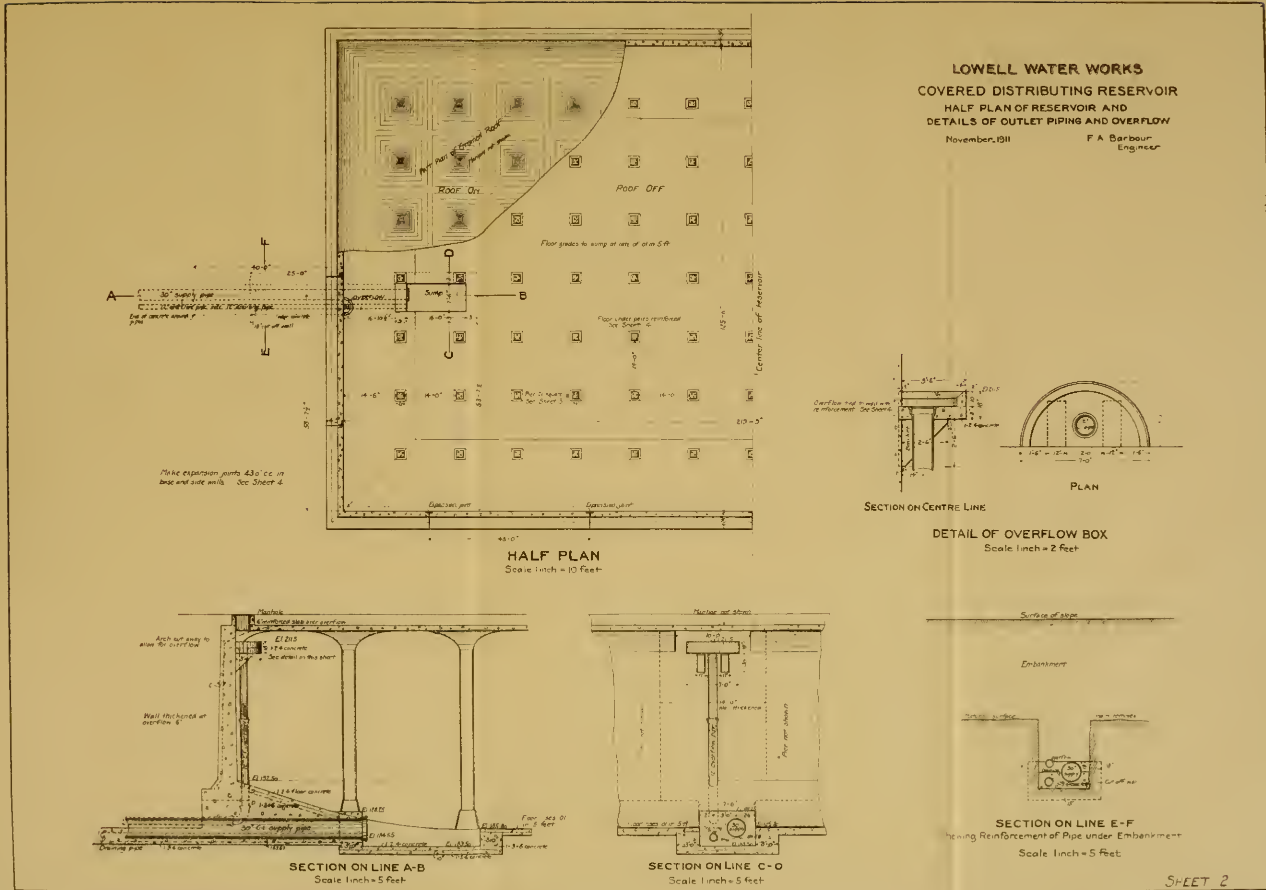
Thomas on
The Lowell Water Works.




LOWELL WATER WORKS
COVERED DISTRIBUTING RESERVOIR
HALF PLAN OF RESERVOIR AND
DETAILS OF OUTLET PIPING AND OVERFLOW
November, 1911
F A Barbour
Engineer
ROOF ON
ROOF OFF
Sump
30" supply pipe
Floor grades to sump at rate of 1 in 5 ft
Centre line of reservoir
Make expansion joints 43'0" c c in
base and side walls. See Sheet 4
Expansion joint
HALF PLAN
Scale 1 inch = 10 feet
SECTION ON CENTRE LINE
PLAN
DETAIL OF OVERFLOW BOX
Scale 1 inch = 2 feet
Manhole
Arch cut away to
allow for overflow
Wall thickened at
overflow 6"
30" C.I. supply pipe
SECTION ON LINE A-B
Scale 1 inch = 5 feet
SECTION ON LINE C-D
Scale 1 inch = 5 feet
Surface of slope
Embankment
SECTION ON LINE E-F
Showing Reinforcement of Pipe under Embankment
Scale 1 inch = 5 feet
SHEET 2

ment. The structure, which is part in excavation and part in embankment, is of concrete, 219.75 ft. long, 125.5 ft. wide, with a depth of 24.0 ft. from the top of the floor to the springing line of the arched roof, and has a capacity of approximately 5 000 000 gal.

The floor is of plain concrete, 10 in. thick, laid in two layers, breaking joints, the lower layer a 1:3:6 mix, and the upper a 1:2:4 mix. The floor rises with a slope of 1 vertical to 3 horizontal from the general level of the bottom to the base of the side walls, lessening the necessary height of these walls to 17.5 ft. above the base, as compared with 24 ft. height of piers, and effecting a material saving in the cost of reservoir per unit of capacity. The material excavated was a hardpan, practically impervious, and incompressible. The floor was, therefore, made a plain slab, without reinforcement, except under the piers, where $\frac{1}{2}$-in. rods in both directions, spaced 12 in. on centers and 6 ft. long, are placed near the lower surface.

The walls are of concrete, reinforced vertically on inside surface as a beam, supported at the top by the roof and at the bottom by the floor, but with an outside and inside projection of base and such reinforcement as a cantilever as would permit backfilling of the wall to a height of 15 ft. before the floor and roof were placed in position, thus enabling 70 per cent. of the total excavation to be deposited in final location at the time of first handling. The base was first placed, and the concrete in walls was then constructed in sections 40 ft. long to the full height, with expansion joints formed of a folded sheet of lead between each section, and with sufficient horizontal reinforcement for temperature stresses to prevent cracking between these joints.

The reinforcement for temperature is carried around the corners, and the first expansion joint is located 20 ft. each side of the corners. The lead sheets $\frac{1}{8}$ in. thick and 8 in. wide projected into the concrete 4 in. each side of the joint, with a fold of 2 in. at right angles to the wall and in the plane of the joint between the sections. The joint in the concrete extended down through the base, but the steel in the base was placed continuously, while that in the walls stopped each side of the expansion joint. Before the completion of the structure, and when the temperature of the air had approached 40 degrees, all of the expansion joints had opened, a

PLATE IV.
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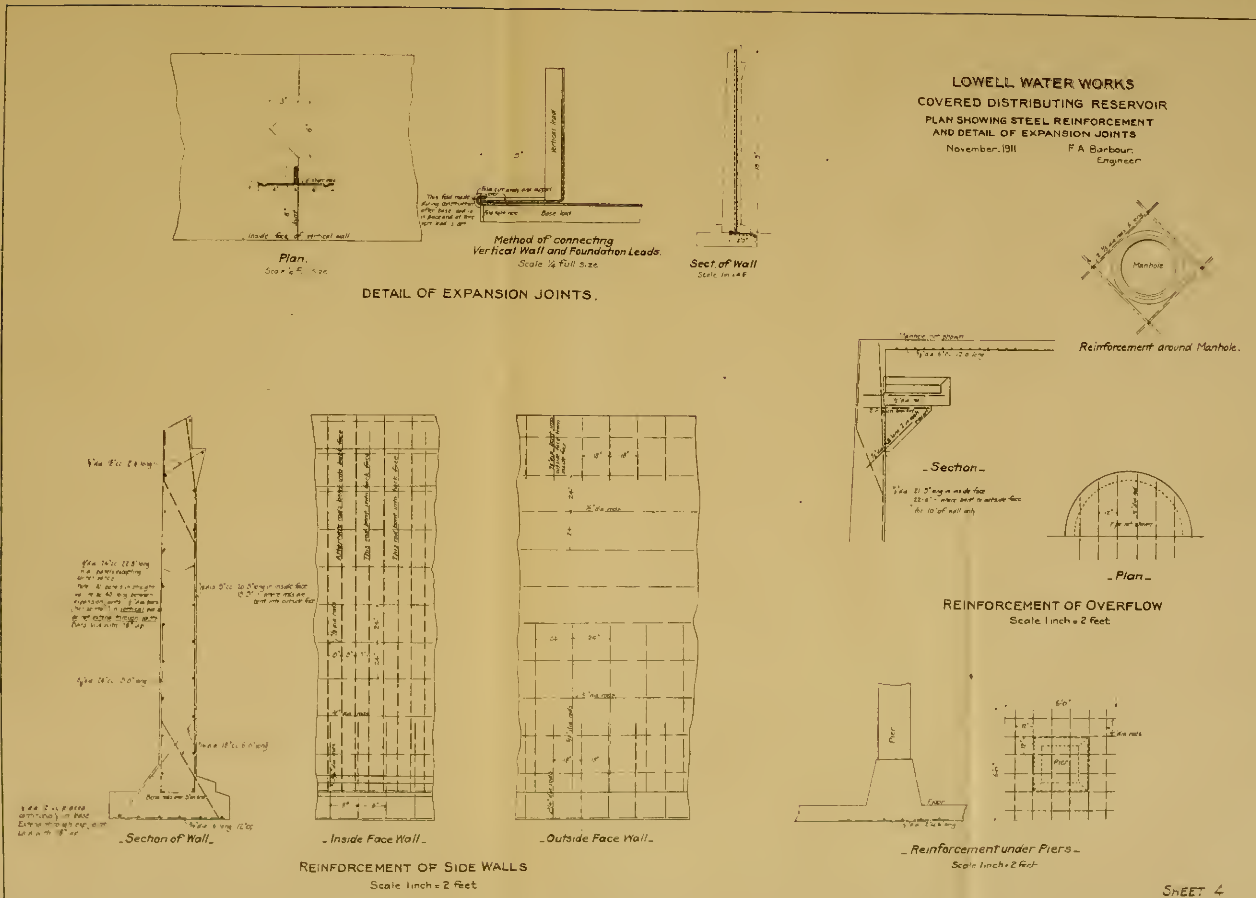
THOMAS ON
THE LOWELL WATER WORKS.



ment. The structure, which is part in excavation and part in embankment, is of concrete, 219.75 ft. long, 125.5 ft. wide, with a depth of 24.0 ft. from the top of the floor to the springing line of the arched roof, and has a capacity of approximately 5 000 000 gal.

The floor is of plain concrete, 10 in. thick, laid in two layers, breaking joints, the lower layer a 1:3:6 mix, and the upper a 1:2:4 mix. The floor rises with a slope of 1 vertical to 3 horizontal from the general level of the bottom to the base of the side walls, lessening the necessary height of these walls to 17.5 ft. above the base, as compared with 24 ft. height of piers, and effecting a material saving in the cost of reservoir per unit of capacity. The material excavated was a hardpan, practically impervious, and incompressible. The floor was, therefore, made a plain slab, without reinforcement, except under the piers, where ½-in. rods in both directions, spaced 12 in. on centers and 6 ft. long, are placed near the lower surface.

The walls are of concrete, reinforced vertically on inside surface as a beam, supported at the top by the roof and at the bottom by the floor, but with an outside and inside projection of base and such reinforcement as a cantilever as would permit backfilling of the wall to a height of 15 ft. before the floor and roof were placed in position, thus enabling 70 per cent. of the total excavation to be deposited in final location at the time of first handling. The base was first placed, and the concrete in walls was then constructed in sections 40 ft. long to the full height, with expansion joints formed of a folded sheet of lead between each section, and with sufficient horizontal reinforcement for temperature stresses to prevent cracking between these joints.

The reinforcement for temperature is carried around the corners, and the first expansion joint is located 20 ft. each side of the corners. The lead sheets ⅛ in. thick and 8 in. wide projected into the concrete 4 in. each side of the joint, with a fold of 2 in. at right angles to the wall and in the plane of the joint between the sections. The joint in the concrete extended down through the base, but the steel in the base was placed continuously, while that in the walls stopped each side of the expansion joint. Before the completion of the structure, and when the temperature of the air had approached 40 degrees, all of the expansion joints had opened, a

straight line extending from the top to near the base of the wall, and varying in width from a hair crack to $\frac{1}{16}$ in.

The walls are 24 in. thick at the base, and 18 in. thick at the springing line, with a projecting lip 6 in. wide to catch the arch concrete of roof and reduce to 14 ft. the span of the outside cylindrical section.

The concrete in base of walls is a $1:2\frac{1}{2}:5$ mix, and above the connection with floor, a $1:2:4$ mix. For size and spacing of the steel in walls, reference may be made to the plans.

The piers are 21 in. square, with a base 2 ft. 6 in. high and 3 ft. square at the bottom, constructed of plain concrete, mixed in the proportion of $1:2:4$. The piers above the base were built to the full height at one filling of the forms, and no difficulty was found in properly joggling the material to place in this depth of form, nor in maintaining the forms to true lines.

The roof is of the groined arch type, with clear spans of 14.0 ft., a rise of 36 in., a thickness at crown of 6 in., and a depression over the piers 21 in. deep. The under side of the arch section is elliptical, the upper surface segmental.

A single 30-in. cast-iron main extends from the pipes leading to the old reservoir, being cross-connected to both force mains and the supply pipe to the distribution system, and serving as both inlet and outlet for the new reservoir. A check valve was placed in the outlet pipe from the old reservoir, thus automatically bringing this reservoir, which it is proposed to keep full and in reserve, into service, should the pressure drop below that, due to its flow line. A large concrete gate chamber was constructed to contain the several gates at the junction of the new and old mains. The 30-in. pipe ends at a point a few feet inside the new reservoir at the present time, although the plan of floor and sump is such that a branch may be inserted and the line extended to the further end of the structure, and the necessary check valves provided, so as to insure circulation, should this prove necessary.

The floor of reservoir slopes to a sump, from which a drain pipe leads to a sewer. A circular concrete overflow weir, bracketed to the end wall with discharge pipe which cannot be closed, prevents the water being raised higher than the intended level, the overflow discharging into the nearby uncovered reservoir.

PLATE V.
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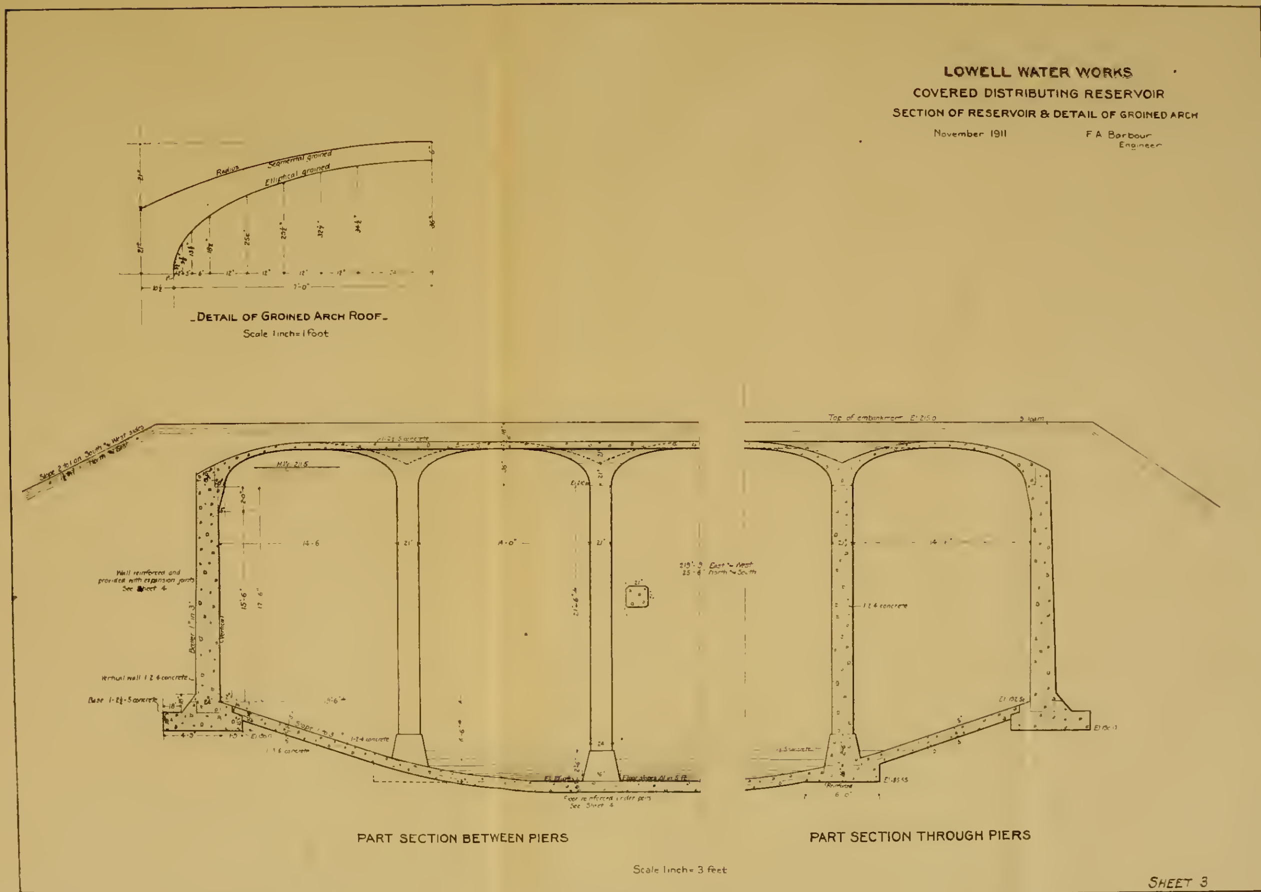

As a matter of public policy, it was thought wise to do all excavation and construct the embankments by day labor. The reservoir was so placed as to balance excavation and embankment, the total quantity of earth work amounting to 15 600 cu. yd., of which 4 800 cu. yd. were spoiled and handled a second time. The cover over the roof, including the loam, is 18 in. deep, the shoulders of the embankment are 6 ft. outside of the inside face of the wall, and the slopes of all high embankments are 2 horizontal to 1 vertical. The 30-in. force main and the construction of the gate chamber at old reservoir were also done by city labor, and the gang was so frequently shifted that no attempt was made to keep a force account of the actual cost of earth work at reservoir.

The masonry work was let by contract to Cyrus Barton, of Lowell, the lowest bidder. Excavation was begun in the fall of 1911, but no concrete was placed until the spring of the present year. The design of the walls, as already stated, provided for the placing of the backfilling at the time of first handling. Accordingly, the first excavation was along the line of the walls to give opportunity for their construction, the core being left for subsequent removal, as the building of the walls provided a place to deposit the material without resort to spoil banks.

The contract prices for masonry were as follows: Concrete in floor, $5.50 per cu. yd.; concrete in wall, $7.95 per cu. yd.; concrete in piers, $10.00 per cu. yd.; and concrete in roof, $9.00 per cu. yd. These prices do not include the steel reinforcement, which was furnished by the city, nor the cement, furnished by the contractor, but paid for separately at the rate of $1.45 per barrel.

The cost of the reservoir, exclusive of excavation and embankment, was somewhat less than $6 000 per million gallons of capacity.

Some requirements of the specifications in regard to concrete may be of interest. Cement was to fulfill the specification of the American Society for Testing Materials; sand was to be in appearance very coarse, but to contain sufficient fine grains to reduce the percentage of voids to a minimum; and the coarse aggregate was to vary in size of particle from ¼ in. to 1½ in. in diameter. In mixing concrete, the right was reserved to change the proportion of sand and coarse aggregate, in order to reduce the

voids so far as possible. The consistency of the mixture was to be such that it could be placed by joggling and spading, but with little or no ramming. Too much water was to be avoided, and the concrete was not to be so wet that there would be a tendency for the coarse aggregate to settle through the mixture. At all horizontal joints beveled bonding pieces were placed, the joints scrubbed with steel wire brushes to expose the aggregate before final set of the concrete occurred, and before placing additional concrete, the joint was thoroughly flushed with water.

Particular attention was paid to the requirement that all concrete should be kept wet for one week after placing, sawdust being spread over the floor and burlap hung over the walls, and both kept saturated with water. It is believed that this provision of ample water to prevent drying out of the concrete is most important in eliminating shrinkage cracks during setting.

The reservoir has been in service since December 6, 1912.

The design and construction of the reservoir, as well as the new pumping station, was in charge of F. A. Barbour, consulting engineer, of Boston, to whom the writer is materially indebted for this paper.

DISCUSSION.

Mr. Thomas. I suppose the part of the paper most interesting to the members is that relating to the driven wells. In Lowell at the present time we are pumping $5\frac{1}{2}$ million gallons from wells. Owing to the addition of new wells last year the iron content is comparatively low, but we believe that as the wells are used it will rise. The question with us, and I suppose the question is the same with other communities which are supplied with driven wells, is, What can be done to prevent the iron content becoming so large as to make the water unsuitable for laundry and certain manufacturing purposes?

In a paper read before the Association some two or three years ago it was suggested that by shutting off the wells and discontinuing their use for a year or two, the water might go back to its former condition; but I think that is very doubtful. I do not believe that that suggestion was based on experience to any great extent, and probably many of our opinions are simply theories and not

FIG. 1.
THE RESERVOIR UNDER CONSTRUCTION.

FIG. 2.
INTERIOR VIEW OF RESERVOIR.

based on practical experience or any demonstration we have of the truth of them.

On the bank of the river only a mile further down the stream from where our wells are, a filter gallery was built in the early days of the water works, as stated in the paper. The water from it was so much cooler than the river water, and so much purer bacterially and chemically, that it was thought to come from the land side. But after ten or a dozen years the water became so foul, so high in iron, and the Crenothrix grew so profusely in it, that the city had to cut it off, and it remained for about ten years without being used. Last summer we turned the water on to the filter gallery for about two weeks, but we were forced to shut it off again because it was almost as bad as it was ten years previously.

It seems to me that this case is analogous to a driven well. Undoubtedly the water was coming from the river. The water looked splendid in the filter gallery when we let it on for several days but it deteriorated rapidly. Now, would not the result be the same in the case of wells that are shut off?

The question, therefore, is as to the treatment of the water. We can get a sufficient quantity of water, but the question is to improve the quality, to eliminate the iron content. Without doubt a great many present have had experience and can give some information in regard to the probability of treating the water so that it can be used.

Mr. F. F. Forbes.* We have had some trouble in Brookline. If we draw too heavily on our wells, the iron increases quite rapidly. We have made some experiments to remove the iron by filtration and we have found that we can remove a large part of the iron, 60 to 75 per cent., simply by aërating and letting the water stand a little while to settle and then filtering it. We may have to filter all our water in that way in order to remove the iron.

Two or three years ago we were drawing heavily on our wells and the iron increased nearly twofold. After the additions were made so that we could draw less heavily on the wells, the iron was reduced to .02 or to .03 in 100 000. We have been using our filter gallery for nearly thirty-eight years, and the water in the gallery is as good as it ever was.

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* Superintendent Water Works, Brookline, Mass.

Mr. Robert S. Weston.* Mr. President, I was very much interested in the paper on the Lowell supply, and especially in the curve which showed the increase of iron in the wells from time to time, followed by decreases when the wells were extended; and I was interested this morning in looking up some of my office records to see how general that experience had been throughout the state.

I found some fifteen or twenty places in Massachusetts supplied with ground water which contained iron. For instance: Billerica, Bridgewater, Cohasset, Dedham, Fairhaven, Hyde Park, Kingston, Lowell, Methuen, Middleboro, Newton, Provincetown, Walpole, Ware, Waltham, Winchendon, Webster, Wellesley, and Woburn. In the beginning in nearly all these places the water contained only a small amount of iron. For instance, in Billerica the iron was only .2 parts per million in 1900, and in 1911, .45. In Bridgewater there was an increase during the period from 1900 to 1906, when the wells were extended, and at the present time the iron is just a little above the permissible limit. Brookline, Mr. Forbes has already told you about. Dedham had no iron in the ground water in 1895, and at present, while there has been an increase of 128 per cent., it is still below the permissible limit. At Fairhaven, Walpole, Ware, and Wellesley, there has been no increase in the iron, but in all these places the area supplying the water is very large in proportion to the consumption, — either the number of wells is large or the wells are in a gravel containing little iron, which yields water very readily. The wells at Lowell between 1895 and 1911, as Mr. Thomas has told you, show an increase to nineteen times the amount of iron that there was in the beginning; those at Brookline, twenty-three times; those at Middleboro, six times; while those at Methuen have increased 168 per cent.; Hyde Park, 437 per cent., and so on. These data are shown in the table on the following page.

It seems that it is almost the rule where ground waters are taken from beneath water-bearing strata which contain bog-iron ore, that sooner or later the iron in the water is bound to increase to a dangerous amount. This is because, as is generally known, the iron is insoluble when there is plenty of oxygen present, but by drawing heavily on the wells the amount of oxygen is exhausted

* Consulting Sanitary Engineer, Boston, Mass.

Iron in Some Massachusetts Waters

Parts per Million.

Town.	Year.									
	1895.	1900.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.
Billerica	.....	0.252	0.432	0.463	0.414	0.362	0.428	0.448	0.450	0.478
Bridgewater	.....	1.377	0.963	1.552	1.100	0.682	0.876	0.412	0.428	0.340
Brookline	0.022	0.068	0.215	0.218	0.287	0.208	0.235	0.465	0.546	0.385
Cohasset	.....	.....	0.300	0.130	0.155	0.150	0.147	.....	.....	.....
Dedham	0.000	0.039	0.055	0.083	0.090	0.043	0.072	0.065	0.089	0.073
Fairhaven	0.138	0.130	0.115	0.202	0.148	0.128	0.135	0.063	0.077	0.120
Hyde Park	0.149	0.340	0.684	0.859	0.720	0.769	0.830	0.783	0.801	.....
Kingston	.....	0.180	0.027	0.030	0.070	0.018	0.120	0.050	0.120	0.086
Lowell	0.119	0.591	0.402	0.439	0.562	0.715	0.743	1.393	2.379	0.836
Methuen	0.133	0.223	0.580	0.365	0.336	0.319	0.366	0.238	0.357	0.887
Middleboro	0.187	0.489	1.170	1.126	1.209	1.349	1.221	1.572	1.598	1.509
Newton	.....	0.029	0.137	0.080	0.063	0.053	0.075	0.097	0.043	0.057
Provincetown	.....	3.774	6.930	6.787	9.750	7.900	7.842	0.056	0.115	0.063
Stoughton	.....	0.047	.....	0.153	0.110	.....	.....	.....	.....	0.123
Walpole	.....	0.146	0.032	0.068	0.077	0.036	0.051	0.053	0.043	0.053
Waltham	0.082	0.086	0.437	0.439	0.744	0.290	0.478	0.575	0.387	0.375
Winchendon	.....	0.112	0.620	0.627	0.660	0.932	0.777	0.970	1.077	0.115
Ware	.....	0.042	0.070	0.090	0.068	0.032	0.059	0.055	0.037	0.038
Webster	.....	0.036	.....	0.160	0.106	0.092	0.114	0.208	0.092	0.117
Wellesley	.....	0.060	0.055	0.072	0.059	0.053	0.059	0.043	0.043	0.047
Woburn	0.023	0.032	0.038	0.035	0.028	0.032	0.034	0.030	0.047	0.046

in burning the organic matter in the soil, and as a result of that process of burning, carbonic acid is produced, and this carbonic acid dissolves the iron. All water-works men know that most iron waters are perfectly clear when first drawn from the ground, but when they are allowed to stand they become, first turbid, then this turbidity becomes red, and finally, if allowed to stand long enough, the red turbidity, which is nothing more nor less than iron rust, settles out and leaves the water above the sediment perfectly clear and practically free from iron.

The only way to remove iron is to get it into an insoluble condition. This is usually accomplished by rusting, — that is, exposing the water in a very thin layer to the action of the oxygen in the air. This will wash out the carbonic acid and make the iron insoluble, and, what is more, get it into particles which are large enough to be strained out subsequently by a sand filter.

Sometimes, where there is a great deal of organic matter from peat bogs, or from other sources, some additional treatment with chemicals is necessary. I am now making some experiments for the Cohasset Water Company, where the amount of organic matter is so high that chemicals may have to be used. The amount of chemicals necessary to be used with such waters as these can be greatly reduced, if their use may not be avoided, by not only aërating the water, but also exposing it to contact with some of the iron which has been precipitated previously. This is accomplished by spraying the water over a pile of coke, gravel, or No. 2 road metal, — that is, material $\frac{3}{4}$ to $1\frac{1}{2}$ in. in diameter. This soon collects a film of iron rust; this moist iron rust attracts the fine iron in the water to it and holds it there until it is oxidized and coagulated. The moist rust accumulates on the stones up to a certain point, then it sloughs off and passes on to the settling basin, where it is removed quite readily and does not clog the filter rapidly. It does not make much difference whether one uses a mechanical filter or a slow filter to remove iron from a ground water. The main thing is to get the iron oxidized and coagulated sufficiently before it is filtered. If you filter water without sufficient pre-treatment, the period between scrapings, or between washings, will be so short that the cost of treatment will be very high.

Out at Superior, Wis., in 1908, we made some experiments to see what was the best method of removing iron from the well water. These wells were located on the island which separates the harbor from Lake Superior, — simply a place where the débris brought down by the very highly colored St. Louis River was thrown up by the action of the waves of Lake Superior. Into this pile, the result of the accumulation of floating organic matter, woody fiber, sand, etc., wells were driven, and the water from these wells was brought across the bay to the pumping station on the mainland. As soon as all these wells were started, all the usual troubles due to the presence of iron were noticed, and it was found that filtration of the water was necessary. A filter was built and the trouble was removed. In this filter the aëration was very thorough, but it was soon found that in this case the organic matter formed a combination with the iron which was extremely

difficult to remove, and the aëration had to be carried just far enough so as to oxidize the iron and not far enough to permit this compound of iron and organic matter to be formed.

I have had a number of experiences of this kind, and I think I can say without any question that all the problems are capable of solution, but the treatment that is essential in one case, and adequate in one case, will not necessarily work in another, due, as I have just said, to differences in the amounts of organic matter and gases present in the water in combination with the iron.

Mr. R. D. Chase.* When that Superior plant, of which Mr. Weston has spoken, started, the water showed up very nicely. So far as the consumers were concerned, however, they could not seem to see that the filter was of very much use, for the water did not appear to them to be any better, but, in fact, decidedly worse. As near as we could make out, the Crenothrix had been growing very nicely in the water without oxygen, but as soon as the water was saturated with oxygen the growth died, fell off and was carried along in the pipes, so that the average householder, when he opened a faucet, would get something which was a fair imitation of thick tomato soup, and he did not like it. It took us some little time to find out just what was happening, and then a very considerable amount of flushing before we could convince the people in the town that the filtration plant was anything but a fake.

Mr. Weston. I would like to ask Mr. Thomas whether or not he has had any trouble due to the clogging of his strainers, because the iron oxidized in the strainers from being exposed to the air? I know that in some of the German plants they are very careful not to let any of their aërated water flow back through the pumps to the wells when they stop for the night, because the air rusts the iron in the well water in the bottoms of the wells and clogs the strainers.

Mr. Thomas. We had occasion to move about fifty of our wells, and we found that the space between the gauze and the well casing filled up with silt and iron rust. The first time we put in the wells, we took the skin of the iron and cut a groove in the shell to hold the gauze. The last two years we just cut a spiral groove, without disturbing the outside of the pipe, and put our gauze on

* New Bedford, Mass.

that. As I say, we found the space filled up full, without any apparent break in the strainer itself. We had the material analyzed by a local chemist and I believe he said it was composed mostly of ferric hydrate. That is about the only evidence we have. When we shut down, the water drains back into the wells from the receiver and from the pumps and the stretch of suction line, and for an hour or so after starting, in fact, for several hours after starting, we are unable to get as much water as we did before we stopped or when we were running right along.

BENDING TEN-INCH CAST-IRON PIPE.

BY CHARLES W. SHERMAN, PRINCIPAL ASSISTANT ENGINEER WITH METCALF & EDDY, CONSULTING CIVIL ENGINEERS, BOSTON.

[*Read February 12, 1913.*]

Probably many of the members of this Association would state as an unquestioned fact that it would be impossible to bend cast-iron pipe, and the remainder would admit that they had never heard of its being done. Seeing is believing, however, and the accompanying photographs (Plate VII), taken by Mr. Leonard Metcalf, show part of a line of 10-in. pipe in which there were about forty lengths which had been heated and bent.

This pipe is a part of the pipe line built for the United Fruit Company, conveying the Guayabo River water to the town of Preston, Cuba. For the greater part of its length it is laid upon the surface of the ground, so that it was possible to photograph the pipe, although it has been in use two or three years.

The canyon through which the pipe passes for about two miles from the dam is crooked, making impossible such easy curves as could be made in the pipe joints. Through somebody's oversight, no curves or sleeves were ordered with this pipe when it was bought; and as it might have taken a month or more to send up and get additional specials, the local engineer — not a water-works man — decided to bend some of the straight pipes. This had been done frequently with steel or wrought-iron pipes for the sugar mill, and they followed the same course of procedure with the cast-iron pipe, with entire success, as they did not break or spoil a single pipe. The pipes were bent to various radii, the shortest being 50 ft.

A cradle of old rails was first constructed with the desired amount of curvature. About one foot at each end of the pipe was left outside the fire, to prevent collapse of the pipe, and a fire of hard wood was built under and around the remainder of the pipes. Six or eight pipes were bent at a time. In one and one-half to

two hours after starting the fires the pipes were hot enough to bend, and settled from their own weight to the cradle prepared to receive them.

These particular pipes were 10 in. in diameter, with $\frac{9}{16}$-in. thickness of shell, corresponding to Class D of the New England Water Works Association Specifications, the weight of which is 760 lb. per 12-ft. length.

Fig. 1.

Fig. 2.

Guayabo River, Cuba, 10-Inch Pipe Line to Preston. Bent Cast-Iron Pipe, October 7, 1913.

REPORT OF COMMITTEE ON WATER CONSUMPTION STATISTICS AND RECORDS.

LEONARD METCALF, CHAIRMAN; FRANK J. GIFFORD, WILLIAM F. SULLIVAN.

[Presented March 12, 1913.]

TABLE OF CONTENTS.

Scope of the Report.

On November 9, 1910, the paper upon "Water Consumption and Statistics Relating Thereto," presented by Mr. Edward S. Cole,* was referred to a committee of three, with the request that the committee give consideration to the most desirable revision of the forms used by this Association for gathering and reporting water consumption statistics and records. Subsequently the scope of the inquiry was broadened to include a discussion of the subdivision of water consumption and of the reasons for the wide variation in daily water consumption per capita found in our American cities.

On April 1, 1911, your committee sent out a circular letter asking for specific information concerning water consumption and rates upon the works with which the members of this Association were connected. The response to this circular was more or less desultory, and after a somewhat voluminous correspondence the committee concluded that it would be wiser and more effective to confine its efforts to getting information from a limited number of works, more or less typical in character, with the operators of which the personal relations of the members of the committee were such as to make it possible to gather reliable data. The data thus collected follow the recommendations contained in this report. They have been quoted at length in order that members might have at hand the essential facts upon which the findings of the committee have been based. Though in no sense complete, the data are believed to be sufficiently broad to be characteristic and significant.

Recommendations of the Committee.

The committee recommends the revision of the forms now used for reporting "Statistics of Consumption of Water" and "Financial Statistics," by the substitution of the following questions for Questions 1 to 12, page 7, and of the following items for Items A to M, page 5, of the "Blank Form for Summary of Statistics Adopted by the New England Water Works Association, September 11, 1902."

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*Journal N. E. W. W. A., Vol. 25, p. 66.

PROPOSED REVISION OF "STATISTICS ON WATER CONSUMPTION," APPEARING UPON PAGE 7 OF BLANK FORM ADOPTED SEPTEMBER 11, 1902.

1. Year for which Report is Made..
2. Population:
   a. Total...
   b. On Line of Pipe..
   c. Supplied..
3. Total Number of Taps...........(Number of Live Taps..............)
4. Average Number of Persons per Tap.................................
   (Found by dividing the Total Population [2*a*] by the Total Number of Taps [3].)
5. Total Number of Metered Taps.....................................
6. Per Cent. Metered Taps...
   (Found by dividing the Total Number of Metered Taps [5] by the Total Number of Taps [3].)
7. How is the Total Water Consumption determined,
   a. By Meter upon Supply Main..................................
   (Yes or no.)
   b. By Plunger Displacement of Pump...........Slip Allowed......%
   (Yes or no.)
   c. By Other Methods. Describe.................................

	Gallons.		Per Cent. of Total Consumption.
8*a*. Total Annual Water supplied for Domestic Uses:			
By Metered Services........................	....	=	....
By Fixture Rate Use........................	....	=	....
b. Total Annual Water supplied for Industrial Uses:			
By Metered Services........................	....	=	....
By Fixture Rate Use........................	....	=	....
c. Total Annual Water supplied for Public Uses:			
By Metered Services........................	....	=	....
By Fixture Rate Use........................	....	=	....
d. Total Leakage or Water-Unaccounted-for........	....	=	....
e. Total Annual Amount of Water supplied..........	....	=	100%

9. Amount of Water supplied:
   a. Total for the Year............................gals.
   b. Average per Day ....gals.
   (Found by dividing Total Annual Amount of Water supplied, shown in [8*e*], by 365* days.)

* Or 366 in case of Leap Year.

c. Average per Day per Tap......................gals.
(Found by dividing Amount shown in [8*e*] by Total Number of Taps shown in [3].)

d. Average per Day per Capita....................gals.
(Found by dividing Amount shown in [8*e*] by Total Population shown in [2*a*].)

10. Cost of Supplying Water, per Million Gallons, figured on Total Maintenance Item [*CC*]........................$.........
11. Total Cost of Supplying Water, per Million Gallons, figured on Total Maintenance plus Interest upon Bonds........$.........
12. Total Cost of Supplying Water per Million Gallons, figured upon Total Maintenance, Depreciation, and Interest upon the Fair Value of the Plant.........................$.........

PROPOSED REVISION OF "FINANCIAL STATISTICS," SHOWN UPON PAGE 5 OF BLANK FORM ADOPTED SEPTEMBER 11, 1902.

Receipts from Water Rates.

A. Fixture Rates for

a. Domestic Uses.......................$.........
b. Industrial Uses......................$.........

c. Total.............................. $.........

B. Meter Rates for

a. Domestic Uses.......................$.........
b. Industrial Uses......................$.........

c. Total.............................. $.........

C. Public Uses for

a. Hydrants............................$.........
b. Fountains...........................$.........
c. Street Watering.....................$.........
d. Public Buildings....................$.........
e. Miscellaneous Public Uses...........$.........
f. ....$.........
g. ....$.........
h.

Total .... $.........

D. Other Miscellaneous Uses:

a....................................$.........
b....................................$.........

c. Total.............................. $.........

Carried forward .... $.........

Brought forward	$. . . . .
E. General Appropriations	$. . . . .
F. From Municipal Departments	$. . . . .
G. From Tax Levy	$. . . . .
H. From Bonds	$. . . . .
I. From Other Sources	$. . . . .
	$. . . . .
	$. . . . .
	$. . . . .
J. Total	$. . . . .

In the column of "*Expenditures*," after the item "FF. Sinking Fund," add on the next line, "FFF. Depreciation Allowance."

At the foot of the page, after item "O. Net Cost of Works to date . . . . $. . . . . ", add the line, "OO. Estimated Fair Value of Works . . . . $. . . . ."

Water Consumption per Capita and per Tap.

The general data relating to water works, from which information was received, are contained in Table 1.

The replies to the circular letters sent out have been lodged in the library of the Association, in a volume entitled, "Report of Committee on Water Consumption Statistics and Records, 1910–1913, Leonard Metcalf, chairman; Frank J. Gifford, William F. Sullivan."

The per capita water consumption in Massachusetts cities in the years 1890, 1900, and 1910, obtained by courtesy of Mr. X. H. Goodnough, chief engineer, Massachusetts State Board of Health, is shown in Table 2.

TABLE 1.

GENERAL DATA RELATING TO THE WATER WORKS FROM WHICH INFORMATION WAS RECEIVED. FOR THE YEAR 1910.

City.	Population.		Taps.		Persons per Tap.	Water Consumption.					Minimum Rate.			Meter Rates per 100 c. f.		
	Total.	Served.	Number Live.	% Metered.		Mgd. Av.	Av. per Cap. Gpd.	Av. per Tap. Gpd.	Max. in % of Av. p. Cap. for 1 mo.	Max. in % of Av. p. Cap. for 1 dy.	% Taps paying only.	$ per Year.	Water Allowed for. Cubic Feet per Year.	Max. Cents.	Min. Cents.	First Step in Scale Cubic Feet per Quarter.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1. Ansonia, Conn...	15 000	10 000	1 010	16%	14.9	1.20	80	1 188	...	...	...	$8	...	18	5	10 000
2. Arlington, Mass.	11 187	10 500	2 065	62	5.4	0.93	84	453	...	...	...	13½	185*	15	11	...
3. Baltimore, Md...	558 485	589 000	110 395	30	5.1	67.5	121	612	116	116	...	6	13 400	...	4.5	...
4. Bangor, Me.....	24 803	...	4 850	20	5.1	4.0	161	825	...	...	...	8	...	55	...	...
5. Bath, Me.......	9 396	...	2 328	...	4.0	1.73	185	746	109	119	...	20	8 000	25	8	...
6. Calais, Me......	7 500	...	1 438	...	5.2	0.70	±94	490	106	...	...	20	8 000	25	8	...
7. Boston, Mass....	670 585	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8. Brewer, Me......	5 600	6 500	1 325	...	4.2	0.75	...	...	...	...	...	...	...	...	...	...
9. Cambridge, Mass.	104 837	104 829	15 905	30	6.6	10.57	101	664	...	...	...	5	3 333	15	7.5	...
10. Canandaigua, N. Y.........	7 300	7 500	1 546	110	4.7	0.86	100	520	127	154	...	8	3 300	6	6	...
11. Claremont, N. H.	7 500	4 500	1 062	...	7.0	...	...	...	...	...	26	12	...	15	7½	...
12. Davenport, Ia...	43 000	...	7 500	67	5.7	4.1	93	533	111	147	65	9	4 000	...	...	...
13. Cleveland, Ohio.	560 663	618 000	83 011	98	6.8	65.7	...	...	...	...	62	2½	at 4¢	...	...	...
14. Denison, Tex....	14 300	11 000	2 125	...	6.7	0.6	56	376	...	192	38	6	...	50	15	...
15. Dover, N. H.....	13 247	12 500	1 901	...	7.0	0.70	53	371	...	...	40	10	...	22½	15	13 333
16. Fall River, Mass.	119 295	118 645	8 501	99	14.0	5.2	44	612	104	124	...	10	...	...	...	...
17. Fitchburg, Mass.	37 000	34 000	5 200	71	7.1	...	...	...	...	...	8	5	...	...	...	...
18. Gardner, Mass...	14 699	13 965	1 732	7	8.5	0.64	46	369	...	...	...	...	...	...	...	...
19. Hartford, Conn..	98 915	121 644	12 621	98	7.8	8.05	66	647	...	...	...	...	...	...	...	...
20. Holyoke, Mass...	57 730	56 901	4 280	8	13.5	5.9	103	1 370	...	...	...	7	...	...	...	...
21. Lawrence, Mass.	85 892	84 000	7 641	98	11.2	3.9	46	518	...	...	8	7	4 600	...	...	...

22. Hyde Park, Mass.	15 506	....	2 521	48	6.2	1.14	74	453	...	...	....	16	6 000	26	18.2	....
23. Jamestown, N. Y.	34 057	32 000	6 504	51	5.2	3.17	99	488	...	...	20	8	4 000	20	6	1 000
24. Johnstown, Pa...	77 000	55 000	10 397	4	7.4	8.75	157	1 460	...	125	62	9	....	27	5	10 650
25. Kingston, Mass..	2 500	2 000	475	.....	5.3	0.30	120	632	...	137	....	....	....	....	....	....
26. Lexington, Mass.	5 000	....	838	57	6.0	0.35	69	427	...	...	42	12	5 333	....	....	....
27. Lowell, Mass....	106 294	106 294	12 494	79	8.2	5.44	51	51	...	...	50	7	5 000	14	10	20 000
28. Manchester, N. H.........	75 000	73 000	6 700	77	11.2	3.8	52	570	...	...	....	10	8 000	12½	8	....
29. Middleboro, Mass.........	8 230	....	1 000	54	8.2	0.34	41	341	...	...	....	9	4 800	18¾	7½	....
30. Milwaukee, Wis.	373 857	400 000	56 490	98	6.6	44.7	112	792	...	...	....	....	....	....	....	....
31. Nantucket, Mass.	3 000	2 500	1 160	0	2.6	0.18	72	155	...	...	....	....	....	....	....	....
32. Nashua, N. H....	27 000	25 000	3 759	25	9.8	2.53	94	670	105	159	....	16	10 700	15	3¾	10 000
33. New London, Conn.........	19 659	19 000	4 132	17	4.8	2.66	140	643	...	...	....	5	4 200	12	4½	7 500
34. Newport, R. I....	25 025	....	5 522	3	4.5	3.93	157	713	...	...	....	....	....	....	....	....
35. New Rochelle, N. Y.........	38 288	37 500	5 810	99	6.6	3.20	85	551	...	...	....	12	5 600	15	....	....
36. Pawtucket, R. I..	51 622	78 919	10 602	86	4.9	6.28	80	593	131	170	....	10	....	22.4	4.5	1 336
37. Peoria, Ill.......	67 000	....	9 170	4	7.3	8.0	119	870	119	154	....	3	2 000	15	4½	....
38. Plymouth, Mass.	12 141	11 000	2 480	4	4.9	1.25	114	505	150	178	2	12	4 800	....	....	....
39. Providence, R. I.	246 000	....	27 818	89	8.8	15.6	63	550	109	137	±36	10	6 667	15	7½	100 000
40. Reading, Mass...	5 818	5 500	1 355	.....	4.3	0.21	37	151	...	...	36	6	1 067	....	....	....
41. Saginaw, Mich...	51 510	....	5 871	6	8.8	9.6	186	1 630	...	...	....	10	12 100	....	....	....
42. Somerville, Mass.	77 236	80 000	12 357	53	6.2	5.9	174	478	...	...	....	6	5 000	12	8	1000000
43. Springfield, Mass.	88 926	87 500	12 545	61	7.1	10.6	121	844	...	...	37	8	3 600	22	5	900
44. Washington, D. C.........	331 000	....	65 215	29	5.1	60.4	182	927	107	150	58	4½	7 500	3	....	....
45. Watertown, Mass.........	12 875	12 800	2 042	100	6.3	0.88	68	431	...	...	33	10	4 000	25	5	....
46. Wilkinsburg, Pa., *et als.*	86 755	86 755	11 788	.....	7.4	7.77	90	658	...	...	....	5	3 333	20	10	1000000
47. Wilmington, Del.	87 400	87 500	18 414	35	4.8	10.3	118	562	...	...	79	5	....	7.5	36	2 000
48. Windsor, Conn. .	4 200	1 200	248	10	16.9	0.07	57	276	...	...	6	6	2 540	24	20	....
49. Woonsocket, R. I.........	38 125	44 200	3 309	96	11.5	1.5	....	.....	117	143	36	10	4 450	22.5	....	....
50. Worcester, Mass.	145 986	156 362	....	.....	.....	10.3	66	.....	...	...	....	4	2 667	15	7.5	61 000

*Gallons per day.

TABLE 2.—WATER CONSUMPTION IN MASSACHUSETTS CITIES AND TOWNS.

(By courtesy of X. H. Goodnough, Chief Engineer, Massachusetts State Board of Health.)

City or Town.	1890.			1900.			1910.		
	Population.	Average Daily Consumption.		Population.	Average Daily Consumption.		Population.	Average Daily Consumption.	
		Gallons.	Gal. per Capita.		Gallons.	Gal. per Capita.		Gallons.	Gal. per Capita.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Abington and Rockland	9 473	312 000	33	9 816	373 000	38	12 383	561 000	45
Andover	6 142	135 000	22	6 813	407 000	60	7 301	627 000	86
Beverly	10 821	743 000	69	13 884	1 003 000	72	18 650	1 702 000	91
Braintree	4 848	161 000	33	5 981	544 000	91	8 066	653 000	81
Bridgewater	7 160	85 000	12	8 831	223 000	25	11 051	245 000	22
Brookline	12 103	877 000	72	19 935	1 941 000	97	27 792	2 476 000	89
Cambridge	70 028	4 566 000	65	91 886	7 304 000	80	104 839	10 458 000	100
Danvers and Middleton	8 378	484 000	58	9 381	677 000	72	10 536	940 000	89
Dedham	7 123	223 000	31	7 457	586 000	79	9 284	1 202 000	129
Easton	4 493	93 000	21	4 837	114 000	24	5 139	124 000	24
Fall River	74 398	2 136 000	29	104 863	3 805 000	36	119 295	5 200 000	44
Framingham	9 239	204 000	22	11 302	433 000	38	12 948	627 000	48
Franklin	4 831	74 000	15	5 017	173 000	34	5 641	343 000	61
Lawrence	44 654	2 778 000	62	62 559	3 317 000	53	85 892	3 879 000	45
Lowell	77 696	5 374 000	69	94 969	7 893 000	83	106 294	5 443 000	51
Lynn and Saugus	59 400	2 657 000	45	73 597	4 680 000	64	97 383	7 027 000	72
Mansfield	3 432	145 000	42	4 006	133 000	33	5 183	387 000	75
Marlborough	8 202	157 000	19	7 582	506 000	67	14 579	541 000	37
Middleborough	6 065	129 000	21	6 885	233 000	34	8 214	341 000	42
Montague	6 296	283 000	45	7 123	446 000	63	8 014	531 000	66
Natick	9 118	264 000	29	9 488	378 000	40	9 866	566 000	57
New Bedford	40 733	4 066 000	100	62 442	6 318 000	101	96 652	7 864 000	81
Newburyport	13 947	426 000	31	14 478	617 000	43	14 949	1 020 000	68
Newton	24 379	985 000	40	33 587	2 086 000	62	39 806	2 505 000	63
Norwood	3 733	169 000	45	5 480	400 000	73	8 014	505 000	63

Peabody	10 158	827 000	81	11 523	1 036 000	90	15 721	2 645 000	168
Randolph and Holbrook	6 420	192 000	30	6 222	233 000	37	7 117	528 000	74
Salem	30 801	2 184 000	71	35 956	2 712 000	75	43 697	3 935 000	90
Taunton	25 448	807 000	32	31 036	1 645 000	53	34 259	2 150 000	63
Wakefield*	13 137	537 000	41	15 487	1 091 000	70	11 404	694 000	61
Waltham	18 707	626 000	33	23 481	2 118 000	90	27 834	2 443 000	88
Ware	7 329	160 000	22	8 263	286 000	35	8 774	401 000	46
Wellesley	3 600	255 000	71	5 072	239 000	47	5 413	331 000	61
Whitman	4 441	87 000	20	6 155	133 000	22	7 292	212 000	29
Woburn	13 499	777 000	58	14 254	1 117 000	78	15 308	2 134 000	139
Averages			46			60			82

* Wakefield and Stoneham combined 1890, 1900; Wakefield only, 1910.

TABLE 3.

Per Capita Consumption and Per Cent. of Services Metered in the Cities and Towns Surrounding Boston, Mass., Supplied from the Metropolitan Water Works, 1904–12 Inclusive.

(By courtesy of Mr. Dexter Brackett.)

City or Town.	1904.		1905.		1906.		1907.		1908.		1909.		1910.		1911.		1912.	
	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent. of Services Metered.	Gals. per Cap. per Day.	Per Cent of Services Metered	Gals. per Cap. per Day.	Per Cent. of Services Metered.
Boston*	149	5.4	150	5.4	148	5.6	153	5.6	153	5.7	143	5.8	130	12.5	124	20.0	125	27.3
Chelsea	116	2.1	109	2.0	97	9.9	97	14.6	104	27.1	89	33.9	87	33.5	80	64.3	85	94.3
Everett	93	1.2	89	1.6	81	1.8	82	2.0	83	2.3	80	9.6	76	15.9	73	22.0	75	28.5
Malden	50	69.3	53	70.5	51	78.1	45	93.6	44	96.1	43	96.3	42	95.6	43	96.3	48	95.8
Medford	93	4.3	97	5.3	98	8.0	102	10.5	94	13.3	77	33.1	61	56.1	50	94.4	49	100.0
Melrose	109	3.1	112	3.2	109	3.3	117	3.9	89	30.9	62	100.0	64	100.0	63	100.0	69	100.0
Quincy	103	3.1	108	3.4	104	3.4	100	14.2	97	24.3	91	29.9	88	29.8	87	36.1	87	62.0
Somerville	92	5.9	89	11.5	89	18.5	90	24.6	89	29.6	83	36.6	80	42.8	74	47.8	79	53.2
Arlington	79	6.0	81	6.4	80	22.1	91	33.6	91	43.3	79	50.1	83	55.2	84	62.8	89	70.4
Belmont	58	100.0	61	100.0	59	100.0	68	100.0	71	100.0	58	100.0	59	100.0	71	100.0	71	100.0
Lexington†	72	1.2	74	1.8	81	2.2	77	2.1	77	11.0	76	33.1	78	46.4	77	56.8	75	69.7
Milton	45	100.0	45	100.0	48	100.0	46	100.0	44	100.0	40	100.0	39	100.0	39	100.0	41	100.0
Nahant‡	70	10.1	74	16.7	69	18.0	69	17.2	70	22.0	60	31.0	58	45.0	65	42.7	69	50.8
Revere§	75	1.9	77	2.3	77	4.0	81	4.7	78	5.6	72	9.7	71	18.4	75	26.0	75	34.9
Stoneham	88	1.6	81	2.0	68	1.7	91	1.9	92	2.3	82	12.8	91	29.7	78	43.3	78	55.4
Swampscott	88	0.0	88	0.0	78	0.0	73	37.8	76	68.3	56	89.2	59	97.2	59	99.1	61	100.0
Watertown	57	92.2	70	92.9	66	93.6	67	98.3	60	100.0	60	100.0	68	100.0	67	100.0	67	100.0
Winthrop	108	0.9	112	1.3	106	1.6	105	2.3	103	3.4	91	17.8	63	66.1	56	95.9	65	100.0
District	128	10.0	129	10.7	126	12.4	130	15.0	129	17.7	119	21.9	110	28.9	105	37.6	107	45.5

* Boston — Includes Hyde Park in 1912.

† Lexington — Allowance made for population not supplied, 1904–12 inclusive.

‡ Nahant and Swampscott — Allowance made for summer population, 1904–12 inclusive.

§ Revere — Includes small portion of Saugus, 1904–8 inclusive.

Year	1904	1905	1906	1907	1908	1909	1910	1911	1912
Lexington*	64	66	73	69	69	68	70	69	68
Nahant*	136	147	135	130	129	108	101	121	120
Swampscott*	104	103	91	85	87	64	66	67	68
District*	128	129	126	130	129	120	110	105	107

* No allowance made for summer population or population not supplied.

The population, per cent. of services metered, and the daily water consumption in gallons per capita, of the cities and towns now comprising the Metropolitan Water District, surrounding Boston, Mass., for the years 1904 to 1911 inclusive, are shown in Table 3, which has been kindly furnished by Mr. Dexter Brackett, chief engineer to the board.

Statistics relating to population, number of services, per cent. of services metered, and water consumption in million gallons per day and in gallons per day per tap or consumer, and per capita, in various other typical American cities, covering a period of one decade or more, are shown in Table 4.

TABLE 4.

Statistics Relating to the Consumption of Water in Various Cities.

(Compiled by Metcalf & Eddy.)

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day.	
					Per Capita.	Per Tap.
			Fall River, Mass.			
1874	44 000	0.51	672	0.78	11.52	760
1875	45 000	0.81	1 147	17	18.02	706
1876	43 000	1.06	1 660	35	24.60	639
1877	45 000	1.17	2 060	42	26.08	569
1878	48 000	1.20	2 324	50	25.09	517
1879	47 000	1.26	2 497	54	26.89	505
1880	48 626	1.36	2 685	59	28.35	507
1890	74 918	2.14	4 980	74	28.51	430
1900	107 623	3.80	6 943	94	35.35	547
1901	107 831	3.62	7 075	95	33.56	512
1902	108 728	4.37	7 282	95	40.15	600
1903	113 602	4.28	7 502	96	37.65	570
1904	113 645	4.09	7 667	96	36.00	534
1905	106 620	4.41	7 744	97	41.34	569
1906	107 911	4.48	7 845	98	41.49	571
1907	112 574	4.94	7 956	98	43.93	621
1908	114 242	4.97	8 108	98	43.48	613
1909	115 097	5.34	8 316	98	46.40	655
1910	119 295	5.20	8 501	99	43.59	611
1911	117 423	5.18	8 790	99	44.09	589

TABLE 4 (*Continued*).

STATISTICS RELATING TO THE CONSUMPTION OF WATER IN VARIOUS CITIES.

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day. Per Capita.	Gallons per Day. Per Tap.
		Brockton, Mass.				
1900	40 063	....	5 275		29.3	220.9
1901	41 610	....	5 467	82.7	29.4	222.4
1902	43 159	....	5 671	90	32.2	240
1903	44 704	....	5 849	90.6	33.0	252.5
1904	46 248	....	6 097	90	35.0	265.6
1905	47 792	....	6 467	90.4	35.6	262.5
1906	57 000*	....	6 820	91	34.3	286.9
1907	59 850*	....	7 208	92	33.9	280
1908	62 400†	....	7 504	100	35.9	298
1909	63 400†	....	7 879	99	35.9	288.9
1910	66 000†	....	8 179	99	36.2	292.7
1911	69 500‡	....	8 426	100	39.0	322
		Lowell, Mass.				
1890	78 000	5.37	8 732	22	69	615
1895	86 500	6.92	9 686	33	80	714
1900	95 000	7.89	10 529	52	83	749
1901	97 000	7.06	10 799	61	73	654
1902	100 000	5.73	10 984	65	57	522
1903	102 000	5.26	11 109	65	51	474
1904	104 000	5.48	11 287	66	52	485
1905	94 889	....	11 451	69	58	478
1906	96 380	....	11 719	71	53	434
1907	96 330	....	11 968	74	57	462
1908	96 380	5.25	12 142	75	55	432
1909	105 000	5.24	12 307	77	50	425
1910	106 294	5.44	12 494	78	51	436
1911	106 294	5.27	12 719	80	50	415
		Lawrence, Mass.				
1880	39 151	1.86	3 224	6	46	577
1890	44 654	2.78	4 864	29	60	571
1900	62 559	3.33	6 079	76	50	548
1901	65 000	3.12	6 240	79	48	500
1902	68 500	3.43	6 375	84	50	537

* Includes Whitman.
† Includes Whitman and Hanson.
‡ Includes Whitman, Hanson, and West Bridgewater.

TABLE 4 (*Continued*).

STATISTICS RELATING TO THE CONSUMPTION OF WATER IN VARIOUS CITIES.

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day.	
					Per Capita.	Per Tap.
		Lawrence, Mass. (*Continued*).				
1903	66 500	2.83	6 483	86	43	437
1904	68 500	2.81	6 581	87	41	428
1905	69 300	3.00	6 680	88	43	449
1906	76 000	3.30	6 811	89	43	484
1907	78 000	3.51	6 970	89	45	504
1908	78 000	3.45	7 095	89	44	487
1909	82 000	3.57	7 416	90	43	481
1910	85 892	3.88	7 641	91	45	507
1911	87 000	3.94	7 802	92	46	505
		Worcester, Mass.				
1896	103 000	6.13	11 947	93	60	513
1897	106 500	6.08	12 330	93.4	57	493
1898	110 500	6.80	12 672	93.6	62	537
1899	114 500	7.63	13 008	94.2	67	587
1900	118 421	8.15	13 202	94.4	69	613
1901	120 500	9.01	13 607	94.3	75	662
1902	122 500	8.21	13 832	94.4	67	594
1903	124 500	9.69	14 129	94.5	78	686
1904	126 500	10.22	14 413	94.5	81	709
1905	128 135	9.64	14 760	96.0	75	652
1906	132 000	9.22	15 061	95.4	70	612
1907	147 084	9.43	15 369	96.2	70	614
1908	143 333	9.06	15 756	96.1	65	575
1909	146 417	8.87	16 263	95.8	62	545
1910	149 538	10.68	16 942	97.1	72	631
1911	155 162	10.34	17 652	97.2	68	586
		Providence, R. I.				
1880	108 923	3.55			33	
1890	141 294	6.74	14 861	62	48	
1900	187 297	10.13	21 566	83	54	470
1901	193 700	10.73	22 186	84	55	484
1902	198 400	11.56	22 758	84	58	508
1903	202 800	13.11	23 332	85	65	562
1904	207 900	13.86	23 881	86	67	581
1905	214 335	14.51	24 482	86	68	593
1906	219 800	15.05	25 094	87	68	601
1907	225 700	16.23	25 709	88	72	631

TABLE 4 (*Continued*).

STATISTICS RELATING TO THE CONSUMPTION OF WATER IN VARIOUS CITIES.

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day. Per Capita.	Gallons per Day. Per Tap.
			Providence (*Continued*).			
1908	231 900	15.55	26 321	88	67	591
1909	237 200	15.16	27 068	89	64	561
1910	246 000	15.57	27 818	89	63	560
1911	254 100	....	28 491*	89*	..	...
		16.59	28 636	....	65	579
			Cleveland, Ohio.			
1880	156 000	10.18	10 013	4.43	65.3	1 016.6
1890	262 000	27.79	30 938	5.80	106.1	898.1
1900	397 200	67.09	53 473	5.87	168.9	1 254.6
1901	411 200†	69.65	55 130	6.42	169.4	1 263.2
1902	417 000†	69.96	56 816	19.88	167.8	1 231
1903	438 000†	62.01	58 852	42.81	141.6	1 054
1904	444 500†	61.57	60 627	50.09	138.5	1 061
1905	462 000†	60.42	64 137	69.70	130.8	918.7
1906	480 000†	59.05	69 128	82.04	123	875.6
1907	501 000†	58.88	72 225	88.60	117.5	815.2
1908	518 940†	52.05	74 490	93.61	100.3	710
1909	564 000†	52.81	76 777	97.31	93.6	687.86
1910	604 073†	61.50	80 686	97.67	101.8	762.57
1911	630 000†	65.69	83 301	98.26	104.3	788.06
			Chicago, Ill.			
1860	109 260	4.70	6 350	....	43	740
1870	306 605	21.77	35 318	....	71	616
1880	491 516	57.38	67 949	....	117	845
1890	1 208 669	152.37	155 096	....	126	980
1900	2 007 695	322.60	308 945	2.1	161	1 044
1901	1 786 226	342.82	315 954	....	192	1 087
1902	1 844 661	358.10	324 202	....	194	1 105
1903	1 903 096	376.02	331 506	....	196	1 136
1904	1 962 251	398.99	339 044	2.4	203	1 177
1905	2 060 000	410.85	345 174	....	200	1 190
1906	2 140 000	436.95	353 872	....	204	1 235
1907	2 250 000	454.62	362 623	....	204	1 252
1908	2 300 000	467.77	372 835	4.05	204	1 253
1909‡	2 163 000	480.91	382 500	3.89	222	1 257
1910‡	2 234 000	518.58	390 000	3.85	233	1 329

* To September 30, 1911.
† Includes suburbs supplied with water.
‡ These figures obtained from 35th Annual Report, Department of Public Works.

TABLE 4 (*Continued*).

STATISTICS RELATING TO THE CONSUMPTION OF WATER IN VARIOUS CITIES.

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day. Per Capita.	Gallons per Day. Per Tap.
			Milwaukee, Wis.			
1885	158 509	16.06	10 990	5	101	1 461
1890	204 468	22.38	17 368	34	107	1 288
1895	249 283	25.29	29 797	53	101	849
1900	285 315	23.63	41 483	68	83	569
1901	300 000	24.07	43 386	72	80	555
1902	308 000	25.01	45 480	74	81	550
1903	325 000	26.27	47 481	77	80	553
1904	333 500	27.94	49 835	78	84	560
1905	342 500	29.65	52 115	80	86	569
1906	350 000	32.11	54 160	81	91	593
1907	360 000	33.73	56 518	82	93	596
1908	370 000	33.80	59 094	83	91	572
1909	380 000	36.11	61 589	83	95	586
1910	380 000	42.52	65 314	98*	111	785
1911	390 000	47.78	56 251	96	112	796
			St. Louis, Mo.			
		Year ending Dec. 31.	Year ending March 31.			
1890	451 700	35.2	38 183	8	78	920
1900	575 238	63.5	65 688	6	111	965
1901	586 400	65.8	67 243	7	112	980
1902	597 600	67.0	69 483	7	112	966
1903	608 800	68.1	72 005	6	112	946
1904	620 000	77.1	74 505	6	124	1 035
1905	631 200	72.1	77 951	6	114	925
1906	642 300	70.4	82 325	5	109	855
1907	653 500	69.2	87 734	5	106	789
1908	664 700	69.3	91 897	6	104	754
1909	675 900	73.7	97 031	6	109	759
1910	687 089	78.2	100 811	6	114	776
			Cincinnati, Ohio.			
1870	220 000	10.44	18 629	0.7	48	561
1875	240 000	14.31	21 336	0.6	60	671
1880	260 000	19.48	23 627	2.3	75	825
1885	310 000	19.80	28 522	4.1	64	694
1890	296 908	33.99	35 439	4.1	114.50	959

* Based on services actually in use — previously based on total number of services.

TABLE 4 (*Continued*).

STATISTICS RELATING TO THE CONSUMPTION OF WATER IN VARIOUS CITIES.

Cincinnati (*Continued*).

Year.	Population.	Consumption, Mgd.	Services.	Per Cent. of Services Metered.	Gallons per Day. Per Capita.	Gallons per Day. Per Tap.
1891	298 723	42.12	36 754	4.2	140.99	1 146
1892	300 550	38.68	37 981	4.4	128.68	1 019
1893	302 389	39.15	39 452	4.4	129.46	993
1894	304 240	41.36	40 988	4.5	135.93	1 009
1895	306 103	47.14	42 272	4.9	154.01	1 115
1896	318 028	44.61	44 774	5.7	140.27	997
1897	319 978	43.93	45 674	5.2	137.30	963
1898	321 940	38.35	46 380	5.5	119.10	828
1899	323 915	39.57	35 942	7.6	122.17	1 100
1900	325 902	38.06	36 215	8.2	116.77	1 050
1901	327 903	40.80	36 829	8.8	124 40	1 108
1902	329 982	43.03	37 302	9.7	130.31	1 153
1903	332 139	45.68	37 942	10.0	137.52	1 204
1904	340 900	48.54	39 308	11.2	142.37	1 234
1905	343 254	44.33	39 308	12.2	129.15	1 127
1906	345 727	50.90	41 037	12.4	147.23	1 240
1907	348 319	45.89	42 765	15.3	131.76	1 073
1908	351 030	41.72	43 922	21.0	118.85	950
1909	355 000	42.42	45 593	27.0	119.50	931
1910	363 591	46.48	47 276	32.8	127.83	984
1911	383 700	48.06	51 366	47.9	125.28	742

Incidentally, the difficulty of getting reliable water consumption statistics is illustrated by a letter received from the water commissioner of one of these cities, in response to inquiry as to the cause for the difference between the published per tap figures and the figures obtained by applying the data contained in the report upon these works. The Commissioner writes, —

"I have made some inquiries of the registrar's department, where they make up the figures of gallons per tap, and find they use the registration of the meters down town, instead of the amount passing through the Venturi meters at the reservoirs. This, of course, makes the figures of no value. I imagine they will change their system and make it accord with the Venturi meter readings."

Error is often introduced, too. by difference in usage, some departments basing their consumption statistics upon total popula-

tion, others upon population served, some upon services, others upon taps, still others upon the number of consumers; and the three latter classes are further subdivided by those works which make use of the total number of services, taps, or consumers, while other works make use of the live services, taps, or consumers. The term "consumer," as applied to taps or services, has been used as practically synonymous with the "family" in Wisconsin. Thus there may be several consumers (or families living independently, with separate kitchen) supplied through one tap, and through one or more meters. In the East, however, it is used to signify the number of persons served.

Table 5, with accompanying diagram, Plate VIII, is reprinted by courtesy of Mr. E. S. Cole, from data collected by him.

Statistics relating to maximum, minimum, and average daily consumption in American cities, based upon the United States Census Bureau Report of 1907, upon "Statistics of Cities," are shown in Table 6.

TABLE 6.

CONSUMPTION OF WATER IN AMERICAN CITIES.

Computed from data in "Statistics of Cities, 1907," United States Census Bureau.

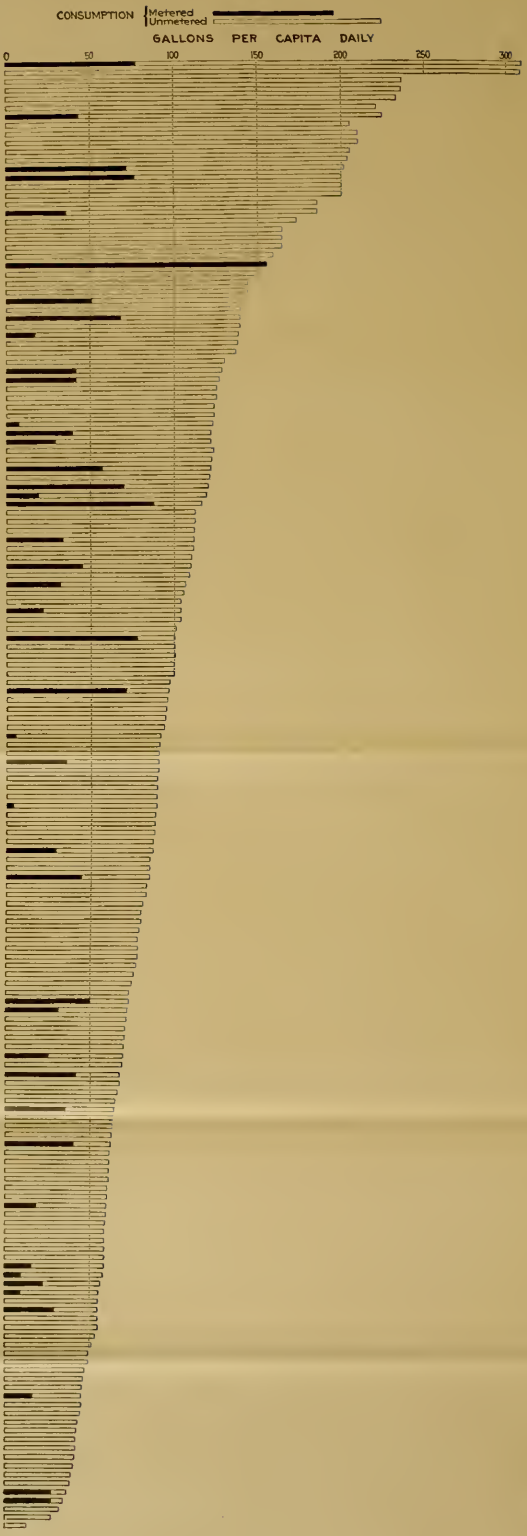
(Note that Average Consumption has been computed by averaging the per capita figures for the several cities.)

Group.	Population.	Number of Cities.	Approximate Average Population.	Daily Consumption of Water. Gal. per Day per Capita. Maximum.	Minimum.	Average.
I	Over 300 000	13	910 000	344	76	164
II	100 000–300 000	22	161 000	230	51	111
III	50 000–100 000	34	71 000	301	40	116
IV	30 000–50 000	44	40 000	398	26	117
Total		113				
Averages			180 000			121
Extremes				398	26	

Statistics relating to 37 English cities, 41 French cities, and 38 German cities, as reported by Debauve and Imbeaux in "Distributions d'Eau," Vol. 2, 1905, converted into American units by Mr. Emil Kuichling, of New York, are shown in Tables 7, 8, and 9 following.

TABLE 6—WATER CONSUMPTION OF CITIES

City	Pop.	Date	Per cent. taps metered
Buffalo, N. Y.	423,700	'11	4.0
Salt Lake City	57,800	'06	2.0
Waco, Tex.	25,000	'12	..
St. John, N. B.	46,000	'08	3.2
Kingston, N. Y.	25,900	'08	
Albany, N. Y.	100,200	'10	23.8
Chicago, Ill.	2,185,200	'11	6.0
Erie, Pa.	66,500	'10	2.5
Pittsburgh, Pa.	363,000	'06	10.0
Bridgeport, Conn.	82,000	'06	5.0
Philadelphia, Pa.	1,599,000	'10	..
Port Huron, Mich.	31,700	'10	
Springfield, Ill.	25,000	'09	17.8
Grand Rapids, Mich.	81,000	'10	42.0
Mobile, Ala.	65,000	'12	10.0
Charleston, S. C.	25,000	'12	3.7
Peabody, Mass.	12,600	'09	..
Auburn, N. Y.	34,600	'11	5.3
Lafayette, Ind.	20,000	'10	9.0
Camden, N. J.	80,000	'08	..
Savannah, Ga.	65,000	'12	2.0
Augusta, Ga.	45,000	'12	5.0
Jersey City, N. J.	267,700	'10	9.0
Columbia, S. C.	27,000	'12	100.0
Jackson, Miss.	21,600	'12	15.0
Greensboro, N. C.	9,000	'12	6.0
Bangor, Me.	21,800	'07-'08	..
New London, Conn.	19,300	'10	15.0
Pawtucket, R. I.	50,000	'08	83.6
Lancaster, Pa.	45,000	'06	30.0
Binghamton, N. Y.	48,400	'10	29.0
Woburn, Mass.	15,200	'10	2.8
Atlantic City, N. J.	37,500	'06	78.4
Montreal, Can.	312,300	'09	..
San Antonio, Tex.	100,000	'12	10.0
Boston, Mass.	674,400	'10	20.0
Cincinnati, Ohio	360,000	'10	32.8
Perth Amboy, N. J.	40,000	'10	29.0
New Brunswick, N. J.	23,300	'10	..
Meridian, Miss.	20,000	'12	14.0
Evansville, Ind.	69,600	'10	..
North Adams, Mass.	23,000	'09	..
Reading, Pa.	98,500	'08-'09	11.9
Baltimore, Md.	575,000	'09	..
Schenectady, N. Y.	72,800	'09	.
Nashville, Tenn.	100,000	'12	74.0
Springfield, Mass.	87,500	'10	60.8
Indianapolis, Ind.	150,000	'09	5.0
Wilmington, Del.	87,500	'10	34.3
Haverhill, Mass.	42,000	'10	17.1
Harrisburg, Pa.	64,100	'11	81.0
Kansas City, Mo.	250,000	'10-'11	44.5
Milwaukee, Wis.	385,000	'11	81.5
St. Louis, Mo.	687,000	'10	6.8
Louisville, Ky.	201,600	'10	8.1
Met. Water Board	1,022,200	'10	37.6
Pittsfield, Mass.	32,000	'10	..
Newark, N. J.	331,000	'09	49.2
Bayonne, N. J.	55,500	'10	99.0
Holyoke, Mass.	56,900	'10	9.0
Cambridge, Mass.	100,000	'10	38.0
Knoxville, Tenn.	60,000	'12	42.0
Plymouth, Mass.	12,100	'10	94.0
Richmond, Va.	127,600	'12	69.0
Peoria, Ill.	73,000	'12	36.0
Cleveland, Ohio	516,000	'08	93.6
Macon, Ga.	50,000	'12	26.5
New York City	4,910,000	'11	..
Austin, Texas	35,000	'12	100.0
Atlanta, Ga.	150,000	'12	100.0
Toronto, Ont.	360,000	'10	4.2
Yonkers, N. Y.	77,500	'09	100.0
Memphis, Tenn.	135,000	'12	..
Holland, Mich.	10,000	'10	96.6
Andover, Mass.	7,000	'07	80.0
Dallas, Tex.	93,000	'12	.
East Orange, N. J.	35,700	'10	18.1
Beverly, Mass.	18,600	'10	4.1
Stoneham, Mass.	7,100	'10	43.3
Poughkeepsie, N. Y.	27,900	'08	89.5
Syracuse, N. Y.	137,200	'08	87.6
Jamestown, N. Y.	31,200	'10	51.0
Salem, Mass.	43,600	'10	89.7
Brookline, Mass.	27,700	'10	..
Waltham, Mass.	27,700	'10	12.0
South Bend, Ind.	53,600	'10	17.8
Quincy, Mass.	32,800	'10	38.0
Utica, N. Y.	74,400	'10	100.0
Duluth, Minn.	78,400	'10	51.5
Chelsea, Mass.	32,500	'10	64.3
Hartford, Conn.	85,000	'09	98.8
Bridgeton, N. J.	14,200	'10	..
New Bedford, Mass.	92,000	'10	47.8
Arlington, Mass.	11,200	'10	62.8
Spartanburg, S. C.	12,000	'12	37.0
Marion, Ind.	19,300	'10	17.3
Rockford, Ill.	45,500	'10	49.2
Fitchburg, Mass.	37,000	'10	70.2
Columbus, Ohio	200,000	'09	80.0
New Orleans, La.	200,000	'12	100.0
Somerville, Mass.	77,600	'10	47.8
Lexington, Mass.	4,400	'10	56.8
Everett, Mass.	33,700	'10	22.0
Washington, D. C.	331,000	'10	25.0
Dayton, Ohio	116,500	'09	74.6
Providence, R. I.	224,300	'11	89.2
Worcester, Mass.	149,500	'10	65.7
Lynn, Mass.	85,300	'08	40.0
Revere, Mass.	18,500	'10	28.0
Manistee, Mich.	14,000	'09-'10	9.0
Galveston, Tex.	40,000	'12	99.0
Hamilton, Ohio	35,200	'09	60.0
Taunton, Mass.	32,500	'11	53.0
Watertown, Mass.	12,900	'10	100.0
Battle Creek, Mich.	27,000	'11	96.0
Toledo, Ohio	195,000	'11	86.0
Jacksonville, Fla.	58,000	'09	70.0
Melrose, Mass.	15,700	'10	100.0
Framingham, Mass.	10,200	'08	77.0
Chicopee, Mass.	25,400	'10	..
Winthrop, Mass.	10,200	'10	95.9
Fort Worth, Tex.	80,000	'12	100.0
Newton, Mass.	39,600	'10	88.6
Fort Wayne, Ind.	63,900	'08	34.5
St. Paul, Minn.	214,700	'10	51.0
Medford, Mass.	23,300	'10	94.4
Covington, Ky.	53,200	'10	100.0
Minneapolis, Minn.	315,000	'09	78.8
Tampa, Fla.	50,000	'12	25.0
Newport, Ky.	35,000	'10	31.0
Topeka, Can.	43,600	'10	68.0
Belmont, Mass.	5,600	'10	100.0
Swampscott, Mass.	6,900	'10	99.1
Westerly, R. I.	12,000	'09	..
Nahant, Mass.	2,100	'10	42.7
Norwood, Mass.	.	'05	..
Natick, Mass.	9,600	'09	65.0
Gardner, Mass.	11,300	'09	7.0
Madison, Wis.	26,900	'09	99.0
Gloucester, Mass.	23,000	'09	5.0
Charlotte, N. C.	20,000	'12	100.0
Lowell, Mass.	96,300	'08	75.3
Aurora, Ill.	33,000	'09	..
Houston, Tex.	105,000	'12	89.0
Attleboro, Mass.	17,500	'10	100.0
Kalamazoo, Mich.	39,400	'10	96.6
Ware, Mass.	9,000	'09	93.0
Fall River, Mass.	114,300	'09	98.8
Wellesley, Mass.	7,000	'09	100.0
Franklin, N. H.	4,800	'08	100.0
Lawrence, Mass.	82,000	'09	90.0
Marlborough, Mass.	13,800	'09	65
Sioux City, Iowa	25,200	'09	100.0
Malden, Mass.	44,700	'10	96.3
Quincy, Ill.	36,500	'10	58.0
Dover, N. H.	13,000	'11	73.0
Methuen, Mass.	12,000	'11	75.2
Lexington, Ky.	45,000	'10	56.8
Danville, Va.	19,000	'08	95.2
Milton, Mass.	7,900	'10	100.0
Middleboro, Mass.	7,000	'05	.
Concord, N. H.	21,500	'10	57.2
Brockton, Mass.	66,000	'10	99.4
Woonsocket, R. I.	42,700	'10	87.0
Reading, Mass.	5,700	'09	97.0
Auburn, Me.	15,000	'10-'11	
Winchendon, Mass.	7,200	'09	85.0



From *Engineering News*, Aug. 22, 1912.

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TABLE 7.

Population, Average Water Consumption and Price per 1 000 U. S. Gallons in 37 English Cities, in Year 1902.

(From Debauve and Imbeaux, "Distributions d'Eau," Vol. 2, 1905.)

City.	Population, Census 1901.	Average Consumption per Head and Day, U. S. Gallons.	Price per 1 000 U. S. Gal. Cents.	
			From	To
Aberdeen	155 000	54.0	11.8	3.4
Ashton	140 000	24.0	33.8	16.9
Belfast	360 000	39.6	16.9	9.3
Birkenhead*	104 920	40.8	19.8	14.5
Birmingham*	775 502	33.6	32.1	10.1
Blackburn*	130 000	30.0	10.1	3.4
Bolton*	237 159	32.4	15.2	10.1
Bournemouth*	85 920	27.6	40.6	20.3
Bradford*	450 000	54.0	15.2	11.8
Briston*	353 374	26.4	30.4	10.1
Cardiff*	190 000	30.0	30.4	10.1
Darlington	46 000	25.2	20.3	6.8
Derby*	129 500	26.4	20.3	7.6
Dublin*	333 300	43.2	10.1	6.8
Dundee*	202 000	60.0	...	10.1
Edinburgh*	435 500	48.6	...	10.1
Glasgow*	1 075 735	67.2	...	6.8
Halifax*	224 933	18.0	13.5	10.1
Leeds*	430 000	42.6	...	10.1
Liverpool*	850 000	37.7	15.2	10.1
London	6 304 653	40.8	20.3	10.1
Manchester*	1 082 000	34.8	40.6	8.5
Newcastle*	485 000	45.5	13.7	8.5
Northampton*	120 000	18.8	...	30.4
Nottingham*	301 000	24.0	16.9	10.1
Oldham*	223 000	27.0	40.6	10.1
Paisley*	101 000	83.2	...	7.6
Plymouth*	132 326	55.2	...	3.4
Portsmouth*	200 000	48.7	30.4	13.5
Rochdale	100 000	22.8	20.3	10.1
Sheffield*	429 552	32.4	16.9	10.1
S. Essex*	146 000	24.0	16.9	13.5
Stockport*	135 000	27.0	...	...
Stockton*	220 000	62.4	30.4	5.1
Swansea*	110 000	34.8	25.4	10.1
Wakefield*	138 000	21.6	...	...
Wolverhampton*	136 000	26.4	27.0	10.1
Averages of 37		37.6	20.4	10.3
			Extreme Range =40.6¢ to 3.4¢.	

* Indicates that adjacent communities are also supplied.

TABLE 8.

Population, Average Water Consumption and Price per 1 000 U. S. Gallons in 41 French Cities, in Year 1902.
(From Debauve and Imbeaux, "Distributions d'Eau," Vol. 2, 1905.)

City.	Population, Census 1901.	Average Consumption per Head and Day, U. S. Gal.	Number of Taps.	Price per 1 000 Gal. Cents.	Average Number Persons per Tap.
Albi	22 571	58.2	1 275	12.6	17.7
Amiens	90 758	24.1	6 600	21.9	13.8
Angers	82 398	37.3	5 000	13.1	16.5
Angoulême	37 650	35.4	1 390	10.2	27.1
Auxerre	18 901	76.2	1 200	17.1	15.8
Avignon	46 786	36.5	2 203	8.0	21.2
Bar-le-Duc	17 693	31.2	840	20.4	21.1
Besançon	55 362	131.0	1 707	13.9	32.4
Bordeaux	256 638	46.3	22 129	16.1	11.6
Boulogne	49 940	38.3	1 698	12.0	29.4
Bourges	46 551	28.0	2 300	12.0	20.3
Brest	84 184	7.1	2 350	45.0	35.8
Caen	44 794	52.0	1 379	17.5	32.4
Calais	59 743	74.5	6 226	14.6–43.8	9.6
Chartres	23 431	26.7	1 300	14.6	18.0
Chateauroux	24 957	24.6	1 000	18.3	25.0
Cherbourg	42 938	32.0	2 011	24.1	21.4
Dijon	71 326	50.2	2 000	18.3	35.7
Épinal	28 080	69.0	1 030	11.0	27.2
Grenoble	68 615	273.0	7 031	4.0	9.7
La Rochelle	31 559	41.2	2 650	18.3	11.9
Le Havre	130 196	31.4	7 141	28.0	18.2
Le Mans	63 227	47.3	3 442	11.0	18.4
Lille	210 696	67.7	10 598	20.4	19.9
Limoges	84 121	29.9	2 450	18.0	34.4
Lyon	459 099	49.7	51 141	16.1	9.0
Mâcon	18 928	50.0	3 100	21.9	6.1
Montpellier	75 950	87.7	2 850	21.9	26.7
Nevers	27 673	21.1	1 200	21.9	23.1
Nismes	80 605	47.3	2 395	14.6	33.6
Orleans	67 311	30.6	5 068	18.7	13.3
Paris (2 systems)	2 714 068	97.8	93 035	25.6	29.2
Poitiers	39 886	24.3	2 330	13.7	17.2
Reims	108 385	52.3	5 000	19.7	21.7
Rochefort	36 458	24.3	1 626	18.1	22.4
Rennes	74 676	51.8	2 192	20.0	34.0
St. Étienne	146 559	54.7	6 500	20.0	22.6
Toulon	101 602	40.2	3 633	12.0	28.0
Toulouse	149 841	70.0	5 000	18.3	30.0
Tours	64 695	54.2	4 350	8.8	14.9
Versailles	54 983	66.8	2 975	20.0	18.5
Averages of 41		53.5		*	

* Maximum = 45.0¢.
Minimum = 4.0¢.
Mean = 17.7¢.

TABLE 9.

Population, Average Consumption, and Price per 1 000 U. S. Gallons in 38 German Cities, in Year 1900.
(From Debauve and Imbeaux, "Distributions d'Eau," Vol. 2, 1905.)

City.	Population.	Average Consumption per Head and Day, U. S. Gal.	Price per 1 000 Gal. Cents.		Per Cent. Water Not Accounted for.
			From	To	
Aachen	135 235	20.6	13.5	9.0	26.3
Augsburg	9 109	55.0	27.0	2.7	5.1
Barmen	141 947	51.0	10.8	6.3	10.0
Berlin	1 884 151	20.6		13.5	8.6
Brunswick	128 177	20.1		9.0	8.3
Bremen	163 418	25.9	13.5	10.8	6.7
Breslau	422 738	22.0	13.5	9.0	14.2
Chemnitz	209 584	11.4	40.5	9.0	...
Cottbus	39 327	12.4	16.2	10.8	...
Danzig	140 539	22.0	36.0	18.0	16.0
Darmstadt	72 019	24.8	19.8	15.3	15.4
Dortmund	142 418	66.0	9.0	4.5	4.5
Dresden	395 349	27.8	10.8	9.7	0.4
Düsseldorf	213 767	28.3	10.8	1.8	5.0
Duisburg	92 929	35.7	9.0	5.0	...
Essen	118 863	38.0	9.0	7.2	10.2
Frankfurt a/M	288 489	62.1	22.5	13.5	8.0
Fürth	54 142	15.9		10.8	14.4
Göttingen	30 234	13.2	20.7	16.2	28.3
Guben	33 096	5.8	18.0	10.8	...
Hamburg	705 738	46.1		9.0	0.2
Hannover	235 666	24.3	18.0	15.3	10.7
Kiel	107 938	16.4		20.7	18.9
Köln	372 229	32.2	13.5	4.5	22.1
Leipzig	455 089	18.0	19.8	14.4	31.3
Mannheim	140 384	22.5	18.0	5.4	15.0
Metz	58 421	34.6	19.8	10.0	39.6
München	499 959	53.6		4.5	0.1
Münster	63 776	21.7	12.6	6.3	10.1
Nürnberg	261 022	19.6	18.0	9.0	12.6
Plauen	73 891	7.8		18.0	...
Solingen	45 249	14.5	19.8	9.9	15.4
Spandau	65 014	11.6	13.5		3.3
Stralsund	31 083	20.6	18.0	10.8	23.7
Strassburg	150 268	27.8		13.5	9.8
Stuttgart	176 318	28.0	27.0	1.8	11.9
Würzburg	75 497	60.8	6.3	4.8	17.9
Zwickau	55 825	17.7	36.0	12.6	4.0
Average of 38		27.8	*		

* Extreme range = 40.5¢ to 1.8¢.
Means = 16.8¢ to 9.9¢.

TABLE 10.

WATER CONSUMPTION STATISTICS FROM GERMAN CITIES AND OTHER EUROPEAN CITIES OR DISTRICTS OF MORE THAN 100 000 POPULATION, ARRANGED IN ORDER OF POPULATION.

(From Report of Committee on Water-Works Management, to the *Deutscher Verein von Gas und Wasserfachmännern, 1910.*)

Number.	Place and District Supplied.*	Business Year.	Population Supplied.	Consumers or Taps.	Number of Hydrants.		Delivery in U. S. Gallons per Capita, Based upon Number of Inhabitants.		
					Above Ground.	Below Ground.	Maximum.	Minimum.	Average.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	Berlin	1908–1909	2 183 531	29 707	7 094	....	32	15	22
2	Hamburg	1908–1909	864 000	24 329	5 244	302	50	30	39
3	Gelsenkirchen	1908	800 000	.....	3 043		86	40	68
4	Charlottenburg	Oct. 1, '08–Sept. 30, '09	720 292	17 273	7 646		39	16	24
5	Leipzig	1908	564 300	10 359	3 203	....	26	11	18
6	München	1908	561 000	16 270	3 611	215	100	57	63
7	Dresden	1908	532 000	16 442	4 054	....	40	17	26
8	Breslau	Apr. 1, '08–Mar. 31, '09	496 896	10 106	3 579	18	34	15	22
9	Cöln	1908–1909	441 700	26 564	4 716		47	27	37
10	Frankfurt	1908–1909	380 315	20 086	1 975	480	51	26	38
11	Frankfurt†	1908–1909	356 724	2 491	1 227	235	13	1.3	4.8
12	Hannover	1908–1909	358 880	12 101	1 942	....	25	14	18
13	Düsseldorf	1908–1909	343 528	14 254	2 497	168	51	22	35
14	Dortmund	1908–1909	331 224	10 490	1 309	18	90	43	67
15	Nürnberg	1908	313 880	12 680	4 059	1 265	31	12	22
16	Mülheim a. d. Ruhr	1908	300 000	7 061	1 122	....	102	45	74
17	Essen	1908–1909	278 707	13 317	1 828		56	28	44
18	Stuttgart	1908–1909	269 709	13 639	3 724	19	43	12	25
19	Chemnitz	1908	269 517	7 722	1 594	30	22	7	13

20	Charlottenburg....	1908–1909	269 479	4 586	1 670		39	16	24
21	Magdeburg.......	1908	247 521	6 897	2 621	....	25	12	18
22	Bremen...........	1908–1909	237 000	31 698	2 033	464	66	31	48
23	Königsberg.......	1908–1909	236 292	6 768	687	176	28	14	20
24	Stettin...........	1908–1909	233 000	4 573	1 981	86	26	10	17
25	Elberfeld.........	1908–1909	202 000	9 059	1 472		44	16	35
26	Altona-Blankenese.	1908–1909	190 837	10 243	1 024	54	47	27	38
27	Bochum..........	1908–1909	186 653	6 888	1 044	3	88	39	73
28	Halle.............	1908	183 996	7 712	1 379	187	31	12	21
29	Kiel..............	1908	181 888	7 450	1 257	17	25	11	18
30	Mannheim........	1908–1909	179 000	9 300	1 475	5	38	16	26
31	Strassburg........	1908	176 000	7 488	3 378	....	52	24	33
32	Barmen..........	1908–1909	164 600	8 610	917	131	54	27	42
33	Danzig...........	1908–1909	158 235	6 697	1 004	13	..	..	24
34	Cassel............	1908	156 200	5 803	1 299	149	29	16	23
35	Aachen...........	1908–1909	151 000	8 841	1 042	....	31	17	26
36	Posen	1908–1909	150 000	2 870	....	885	33	13	22
37	Braunschweig.....	1908–1909	144 000	7 242	880	197	30	14	21
38	Basel.............	1908–1909	137 500	10 117	2 344	....	34	13	26
39	Mülheim a. d. Rhine	1908–1909	137 448	7 613	973	....	37	16	28
40	Duisburg.........	1908–1909	135 116	8 774	1 299	....	49	21	39
41	Crefeld...........	1908–1909	127 377	9 053	1 295	....	49	14	35
42	Karlsruhe.........	1908	123 300	5 149	1 059	....	52	18	31
43	Mülhausen........	1908–1909	118 000	7 206	1 322	....	49	14	31
44	Weisbaden........	1908–1909	113 000	5 915	1 469	26	42	20	29
45	Meissen..........	1908–1909	112 600	5 569	1 411	75	31	7	16
46	Plauen...........	1908	111 920	5 671	778	4	17	10	11
47	Witten...........	1908–1909	104 016	1 911	290	....	61	32	52
48	Lichtenberg.......	1908	102 307	933	....	....	26‡	9‡	13‡
	Averages......						44.1	19.6	30.8

* City names only refer to the district supplied, which in many cases had many times the population of the city proper.

† River water without filtration for industrial purposes.

‡ Only Lichtenberg proper.

TABLE 10 (*Continued*).

WATER CONSUMPTION STATISTICS FROM GERMAN CITIES AND OTHER EUROPEAN CITIES OR DISTRICTS OF MORE THAN 100 000 POPULATION, ARRANGED IN ORDER OF POPULATION.

Number.	Place.	Business Year.	Population Supplied.	Consumers or Taps.	Number of Hydrants.		Delivery in U. S. Gallons per Capita, Based upon Number of Inhabitants.		
					Above Ground.	Below Ground.	Maximum.	Minimum.	Average.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
49	Vienna, Austria....	1908	1 999 630	33 937	1 913	1 986	18	8	14
50	Amsterdam, Holland...........	1908	565 632	43 469	5 139	117	{ 21 11*	11 4*	15 8*
51	Copenhagen, Denmark...........	1908–1909	447 000	....	2 100	500	37	17	28
52	Stockholm, Sweden	1908	338 521	8 041	1 790	....	36	15	26
53	Riga, Russia......	1909–1910	270 000	4 095	1 065	....	31	13	20
54	Zurich, Switzerland	1908	175 000	10 359	3 203	....	..	..	..
55	Krakau, Austria...	1908	147 701	2 235	544	99	145	66	111
56	Genf, Switzerland..	1908	125 000	7 197	1 030	....	..	..	225†
57	Brunn, Austria....	1908–1909	119 908	3 042	968	....	45	18	31

* These figures refer to river water for public and industrial purposes.

† Not typical, as a very large number of water motors are used.

It will be noted that the average daily consumption, in United States gallons per capita, shown in Tables 6 to 8, is as follows:

Country.	Number of Cities.	Average Daily Consumption U. S. Gal. per Capita.
United States	113	121
England	37	38
France	41	54
Germany	38	28*

Later information concerning water consumption statistics in German cities, and of a few other European cities or districts, is contained in an admirable report of the *Deutscher Verein von Gas und Wasserfachmännern*, on "*XXI Statistische Zusammenstellung der Betriebs-Ergebnisse von Wasserwerken*," published in 1910, which has been abstracted for cities or districts having a population of over 100 000, and converted into American units by Metcalf & Eddy, in Table 10. From this it will be noted that the average daily consumption reported is approximately 31 U. S. gallons per capita in the 48 German cities referred to.

One is immediately struck in studying such statistics by the tremendous variation in the daily per capita water consumption.

To what is this variation due? Your committee is of the opinion that it is due chiefly to the difference in the use of water for industrial purposes, and in less measure to the method of selling the water, whether by flat rates or meters; to the difference in character of population and life of the community; to public uses; and to the waste or losses from the pipe system and fixtures. Climatic conditions also have some influence upon consumption. Thus in the high, dry, semi-arid regions of the middle West it is reasonable to anticipate greater use of water for the sprinkling of lawns and for watering streets, which will increase substantially the per capita daily consumption. Illustrative examples of these several influences are submitted in the following pages.

Classification of Water Consumption.

Water consumption may be classed broadly under the following heads:

* See also Table 10.

1. Domestic uses.
2. Industrial uses.
3. Public uses.
4. Leakage and Unaccounted-for Water.

The variation in the domestic use of water by different classes of buildings or consumers is interestingly shown in Table 11, containing the replies received to the circulars sent out. The classification indicates an average water consumption of 64 gallons per capita per day in apartment houses, 55 in first-class dwellings, 34 in middle-class dwellings, and 15 in lowest-class dwellings.

The classification referred to was still more closely defined in two cases, as follows: —

By Mr. C. M. Saville, chief engineer, Board of Water Commissioners, Hartford, Conn., —

"Apartment Houses A. These are strictly first-class flats, the best kind in the city, similar to the Charlesgate in Boston, being, perhaps, 5-room suites renting from $35 to $50 a month, with bath, hot and cold water, janitor service, etc., and each building having from 16 to 24 suites.

"Apartment Houses B. These consist of the better class of 6- and 8-room tenement buildings, renting, perhaps, from $15 to $20 a month, having about 5 rooms and a bath, but with no heat or janitor service.

"First-Class Residence District. Class A houses include the very best dwellings in the city, the estates being worth, perhaps, from $50 000 to $60 000, 15 to 20 rooms, and all the modern plumbing that would go with this class of building, similar to the largest and finest estates in Brookline, the Newtons, and Milton.

"Class B includes dwellings worth from $12 000 to $18 000, fully plumbed 12-room houses, with baths, toilets, etc., similar to the single dwellings that may be found on West Newton Hill, Chestnut Hill, and in Brookline on the north side of Beacon Street, west of Coolidge Corner."

TABLE 11.

WATER CONSUMPTION PER CAPITA IN HOUSES OF DIFFERENT CLASSES, IN COMMUNITIES FROM WHICH REPLIES WERE RECEIVED. YEAR 1910 OR 1911.

City.	Apartment Houses.			First-Class Dwellings.			Middle-Class Dwellings.			Lowest-Class Dwellings.		
	No. of Houses.	No. of Persons.	Gal. per Day per Capita.	No. of Houses.	No. of Persons.	Gal. per Day per Capita.	No. of Houses.	No. of Persons.	Gals. per Day per Capita.	No. of Houses.	No. of Persons.	Gal. per Day per Capita.
Baltimore, Md.	...	...	...	...	...	...	20	126	54	25	84	16
Boston, Mass.	50	2 164	37	40	400	60	50	750	33	{ 50	750	15
Boston, Mass.*	...	...	...	...	...	...	...	...	...	{ 50	7 000	24
Cambridge, Mass.	50	1 242	37	50	250	37	50	300	11	50	250	17
Canandaigua, N. Y.	50	248	62	50	290	68	50	180	42	50	146	10
Denison, Tex.	...	...	...	50	153	15	200	799	12	500	3 090	4
Fall River, Mass.	...	...	...	60	328	63	60	457	26	60	1 394	17
Hartford, Conn.	19	560	55	114	659	67	135	1 186	27	98	1 842	24
Hartford, Conn.	75	1 247	24	148	749	43	...	...	...	...	...	...
Holyoke, Mass.	20	2 215	46	15	92	50	20	113	43	...	...	...
Holyoke, Mass.	47	2 118	69 = (apartments with stores)									
Pawtucket, R. I.	...	...	...	...	...	...	482	4 095	26	766	7 188	12
Pawtucket, R. I.	...	...	...	...	...	...	...	...	...	444	4 534	12
Peoria, Ill.	5	150	84	5	30	74	20	80	32	5	15	11
Peoria, Ill.	5	200	63	13	104	47	25	125	28	8	40	6
Plymouth, Mass.	...	...	...	23	94	47	15	67	33	2	4	14
Washington, D. C.	101	3 470	135	84	500	75	100	400	30	100	500	37
Wilmington, Del.	25	500	73	25	189	73	25	125	44	...	...	...
Worcester, Mass.	50	1 875	60	50	277	42	50	385	66	50	1 179	12
Totals	497	15 989	...	727	4 115	...	1 302	9 188	...	2 258	28 016	...
Averages			62			54			34			15

* Lowest-class dwellings, lower figures = those for tenement blocks containing from 15 to 30 families each.

By Mr. G. W. Batchelder, water commissioner at Worcester, Mass., who submitted the following fundamental data relating to the 50 examples examined under each class, —

	Apartment Houses.	First-Class Dwellings.	Middle-Class Dwellings.	Lowest-Class Dwellings.
Sinks	453	72	102	218
Basins	516	169	92	1
Baths	449	102	96	5
Water-Closets	479	156	108	157
Set Wash Tubs	816	135	87	...
Hose	50	58	56	4
Boilers for Heating	40	32	17	...
Tank in House	410	50	76	...
Elevators	18	1	...	...

Mr. Dexter Brackett, chief engineer of the Metropolitan Water Works of Boston, has courteously placed at the disposal of the members of your committee the following data recently prepared by him, based upon the Metropolitan records for the year 1908, with populations based upon the State Census Report for the year 1905.

TABLE 12.

WATER CONSUMPTION IN DWELLINGS OF DIFFERENT CLASSES IN THE METROPOLITAN WATER DISTRICT FOR THE YEAR 1908. POPULATIONS BASED UPON STATE CENSUS OF 1905. (By courtesy of Dexter Brackett, Chief Engineer.)

	Number.	Estimated Population.	Gal. per Capita per Day.
BOSTON, MASS.			
Houses, single*	8	37	140.9 *
2-family	5	48	37.5
3-family	9	129	61.2
4-family	20	382	29.5
5-family	25	598	76.2
6-family	36	1 032	52.2
7-family	31	1 037	35.5
8-family	278	10 631	28.0
9-family	86	3 700	27.5
10-family	65	3 107	50.3
11 to 20-family inclusive	113	7 849	35.3
21 to 30-family inclusive	18	2 199	44.3
Over 30-family	9	1 640	25.1
Combined houses and stores	505	21 410	29.9
		53 799	33.0 Average

* Including some stables and garages. Note the very small number of premises included.

TABLE 12 (*Continued*).

WATER CONSUMPTION IN DWELLINGS OF DIFFERENT CLASSES IN THE METROPOLITAN WATER DISTRICT FOR THE YEAR 1908. POPULATIONS BASED UPON STATE CENSUS OF 1905.

	Number.	Estimated Population.	Gal. per Capita per Day.
SOMERVILLE.			
Houses, single	1 249	5 283	30.0
2-family	1 329	11 243	23.9
3-family	314	3 985	23.8
4-family	82	1 387	26.1
Others	98	2 669	27.5
Boarding houses	15	...	...
Combined houses and stores	130	1 667	23.5
		26 234	25.6 Average
MALDEN.			
Houses, single	4 168	18 548	20.0
2-family	1 799	16 011	14.6
3-family	108	1 442	18.5
Others	45	1 018	19.6
Boarding houses	23	350	20.0
Combined with stores	105	625	20.0
	(Estimated)	37 994	17.6 Average
CHELSEA.			
Houses, single	94	431	49.4
2-family	211	1 937	25.2
3-family	494	6 804	25.9
4-family	62	1 139	21.9
Others	46	1 253	25.8
Boarding houses	2	...	...
Combined houses and stores	209	2 373	24.9
		13 937	26.1 Average
EVERETT.			
Houses, single	20	87	41.2
2-family	4	35	27.1
3-family	10	130	27.7
Others	3	82	49.3
Houses combined with stores	14	61	14.8
		395	33.1 Average
QUINCY.			
Houses, single	1 151	5 456	27.4
2-family	204	1 934	22.2
3-family	30	427	17.9
Others	6	200	27.0
Boarding houses	27	310	25.0
Combined houses and stores	13	64	24.9
		8 391	25.6 Average

TABLE 12 (*Continued*).

WATER CONSUMPTION IN DWELLINGS OF DIFFERENT CLASSES IN THE METROPOLITAN WATER DISTRICT FOR THE YEAR 1908. POPULATIONS BASED UPON STATE CENSUS OF 1905.

	Number.	Estimated Population.	Gal. per Capita per Day.
MEDFORD.			
Houses, single	168	739	32.3
2-family	220	1 936	22.7
3-family	21	277	23.7
Others	6	123	21.0
Combined houses and stores	39	484	23.2
Boarding houses	8	...	...
		3 559	24.8 Average
Private lawns	3		
MELROSE.			
Houses, single	884	3 740	29.5
2-family	18	152	44.7
Others	9	173	31.6
Combined houses and stores	20	169	31.7
		4 234	30.2 Average
REVERE.			
Houses, single	60	266	40.9
2-family	28	248	36.5
3-family	32	424	33.9
		938	36.6 Average
WATERTOWN.			
Houses, single	1 023	4 869	19.5
2-family	475	4 522	15.0
3-family	34	486	12.5
4-family	31	588	14.6
Others	16	500	12.9
Boarding houses	11	154	14.2
Combined houses and stores	30	180	15.7
		11 299	16.7 Average
ARLINGTON.			
Houses, single	452	2 133	34.0
2-family	172	1 624	28.7
3-family	26	368	32.6
Others	11	255	34.5
Combined houses and stores	2	24	29.9
Boarding houses	6	...	...
		4 404	31.9 Average
Private lawns	5		

TABLE 12 (*Continued*).

WATER CONSUMPTION IN DWELLINGS OF DIFFERENT CLASSES IN THE METROPOLITAN WATER DISTRICT FOR THE YEAR 1908. POPULATIONS BASED UPON STATE CENSUS OF 1905.

	Number.	Estimated Population.	Gal. per Capita per Day.
WINTHROP.			
Houses, single	29	124	47.2
2-family	18	154	40.7
3-family	7	90	34.4
Others	5	120	15.5
		488	35.3 Average
MILTON.			
Houses, single	996	4 751	29.8
2-family	122	1 164	14.9
3-family	3	43	22.6
4-family	2	38	10.6
Boarding houses	1	...	...
Combined houses and stores	1	4	9.0
		6 000	26.7 Average
SWAMPSCOTT.			
Houses, single	551	2 149	37.2
2-family	81	632	27.2
3-family	3	35	27.0
Others	1	24	27.3
Combined houses and stores	5	31	27.0
Boarding houses	1	...	...
		2 871	34.7 Average
LEXINGTON.			
Houses, single	80	355	38.3
2-family	2	18	41.1
		373	38.4 Average
BELMONT.			
Houses, single	433	2 169	23.8
2-family	134	1 342	17.1
3-family	36	540	17.1
Others	14	301	18.4
Boarding houses	1	...	...
Combined houses and stores	4	50	15.4
		4 402	20.5 Average
NAHANT.			
Houses, single	88	370	73.9
Others	2	34	39.0
		404	68.6 Average

In Table 13 are shown some Wisconsin data courteously furnished by Mr. Frank A. Newton, formerly assistant statistician of the Wisconsin Railroad Commission.

TABLE 13.

WATER CONSUMPTION DATA, FROM WISCONSIN.

(By courtesy of Mr. Frank A. Newton, Assistant Statistician, Wisconsin R. R. Commission, April, 1912.)

Madison, Wis.

(Practically all metered.)

Class.	No.	Average Consumption in Cubic Feet per Year.		Average Consumption in Gal. per Day per Capita.*
		Per Meter.	Per Consumer.	
Residence	3 009	4 109	4 099	21
Flat buildings.				
1-flat	77	3 887	3 887	20
2-flat	1 328	5 143	2 572	14
3-flat	150	11 340	3 780	19.5
4-flat	44	10 413	2 603	13.5

Jefferson, Wis. All consumers metered.

Population about 3 000. No large industrial users. Large number have no sewer connections. Total residence consumers, 200.

92 used between 2 000–5 000 cu. ft. per year.

46 used between 2 000–3 000 cu. ft. per year.

84 used less than 2 000 cu. ft. per year.

Average (4 persons to family) for residence consumers = 14.2 gal. per day per capita.

Janesville, Wis. Thirty per cent. metered — three fourths of meters on residences.

Residences having meters a selected class, having lawn sprinkling connections. Average use per residence per day = 105 gal.

Superior, Wis.

Sold through meters, 245 335 500 gal.

Of 4 360 commercial and industrial consumers, 3 142 are metered.

3 100 commercial metered consumers.

* Assuming 4 persons to the family.

Deducting metered industrial sales there were about 163 000 000 gal. delivered to commercial meters.

Sales per metered commercial use, 52 870 gal. per year.

Sales per metered commercial use, 144 gal. per day.

At Elmira, N. Y., it was found that the average consumption registered by 2 124 meters, during the year ending February 1, 1912, was 19.6 U. S. gal. per day per capita, on the basis of 5.7 persons per consumer.

In a recent rating case (1912) Mr. William C. Hawley, superintendent of the Pennsylvania Water Company, analyzed the records of 2 000 consumers picked at random from the ledgers of the company, for the purpose of comparing the rates charged and based upon the actual amount of water consumed, with the flat rates which the company might have charged under its contract, and with the flat rates charged by the city of Pittsburgh at the present time. These 2 000 consumers were divided among 17 districts, in proportion to the number of the consumers in each district, and in general every sixth consumer was taken throughout the entire list. If it was found that any particular consumer was a mixed or commercial consumer, or that the meter had not registered during the full term, or if there was any other cause making the account unfair for comparative purposes, the account of the next consumer was taken; and in this way there was obtained an impartial record of metered domestic water consumption, confined to houses and a very few flats or apartments. The total consumption by the 2 000 consumers, for the period of one year, was found to be 10 441 208 cu. ft., or 5 221 cu. ft. per year per consumer, which is equivalent to 39 155 gal. per year per consumer, or 107 gal. per day per consumer, which, on the basis of 5 persons per house, which is probably a little low, is equivalent to 21.4 gal. per day per capita.

By courtesy of Mr. Hofmeister, of the American Water Works and Guarantee Company, record has been obtained of the domestic water consumption in another city located in the vicinity of Pittsburgh. The average consumption of 4 801 domestic services was (1912) 116 gal. per day per tap, or probably slightly less than 23 gal. per capita per day.

In six other places in this vicinity, with a total number of taps in

each, ranging from a little over 1 000 to slightly less than 5 000, for a total number of 17 222 taps, the consumption ranged from 78 gal. per tap per day, for the smallest, to 116 for the largest of these communities, the weighted average per tap being 99.5 gal. per tap per day. Upon the basis of five persons per tap, this gives an average use of 20 gal. per day per capita. The properties considered in these communities were dwellings, — commercial, industrial, and apartment houses being excluded.

In works serving in the year 1912 approximately 237 000 population, in one of the leading coal mining districts of Pennsylvania, it was found that while the per capita consumption was approximately 122 gal. per day, the average domestic consumption for approximately 150 000 population was but 89 gal. per day per consumer, or 17 gal. per day per capita.

At Champaign and Urbana, Ill., where the University of Illinois is located, the average metered domestic consumption based upon 27 600 population and 3 246 consumers, was 122 gal. per day per consumer, or 15.4 gal. per day per capita.

An interesting investigation of the water consumption of 390 typical water services at Pittsburgh, Pa., upon which meters had recently been installed, was made by Mr. Morris Knowles, in 1911, incident to the Pennsylvania Water Company rating case referred to above:

Mr. Emil Kuichling, March 11, 1912, has furnished the following facts concerning observations made at Rochester, N. Y.

"Another interesting record of purely domestic consumption in Rochester, N. Y., is afforded by an examination of 101 meter accounts of small dwellings, which was made in February, 1910, at my request by Mr. B. C. Little, C.E., superintendent of the water works. The data are as follows:

	Gallons per Head per Day.
32 Services into dwellings having both water-closet and bath, and averaging 3 occupants each	22.0
34 Services into dwellings having water-closet, but no bath, and averaging 4 occupants each	16.0
35 Services into dwellings having neither water-closet nor bath, and averaging 4 occupants each	14.5
Total, 101 Services running into as many dwellings, having an aggregate of 372 occupants, and consuming an aggregate of 6 318 gallons per day on the average	17.0

"In this list only 13 services used less than 10 gal. per head per day, the smallest consumption being in a household of 8 persons using 7.0 gal. per head per day on the average throughout the year.

"Mr. Little also remarks that in the better class of dwellings the per capita consumption, according to the meter records, ranges from 25 to 150 gal. per day. In his own household of six persons (including two maids), residing in a 10-room dwelling with 3 bathrooms, the average consumption is 41 gal. per head per day; and he adds that the water fixtures therein are kept in good order."

At New Orleans, Mr. George G. Earl reports that of the ordinary domestic consumers using $\frac{5}{8}$-inch meters, about one third use less than 75 gal. per day, one third use from 75 to 170 gal. per day, and one third above 170 gal. per day. Assuming families of five, this indicates that one third of the small consumers use less than 15 gal. per capita per day, one third from 15 to 35 gal., and one third over 35 gal. In other words, in New Orleans the present average consumption is about 35 gal. per capita per day, for ordinary domestic consumers.

TABLE 14.

MEMORANDA OF AN INVESTIGATION OF 390 TYPICAL WATER SERVICES AT PITTSBURGH, PA.
(Courtesy of Mr. Morris Knowles and the Pennsylvania Water Company.)

During the year 1911 a study was made of 390 services in the city of Pittsburgh, for the purpose of ascertaining the relation of charges on a flat-rate basis to those on a meter basis. The services investigated were picked to cover all classes of domestic use and all sections of the city. The data as to flat assessment, meter readings, amount of charges, and number of rooms in the house were taken from the water assessor's book. The number of persons residing on the premises supplied was obtained by visits to the property.

The investigation was confined to residential properties only, no flat buildings, tenement houses, residences, and stores or any place of business were included. The services include all those paying for water on a meter basis with a rate of 18 cents per 1 000 gallons. The placing of meters being optional on the part of the consumer in Pittsburgh, the majority of domestic consumers are on the flat-rate schedule.

The tabulation is made in the order of flat-rate assessment, assuming that the class of service furnished is gaged somewhat by the charge which would have been made if assessed on the flat-rate basis.

Flat Rate. Dollars.	Services Investigated.	No. of Persons.	No. of Rooms.	Av. No. of Persons per Service.	Total Gallons Water used Yearly.	Average Gallons per		
						Service per Year.	Person per Day.	Service per Day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$3 to $4	1	5	3	5.0	24 400	24 400	13	67
4 to 5	4	20	16	5.0	95 700	23 920	13	66
5 to 6	3	18	17	6.0	185 500	61 830	28	169
6 to 7	8	33	43	4.1	253 600	31 700	21	87
7 to 8	12	52	56	4.3	347 400	28 950	18	79
8 to 9	14	67	84	4.8	597 200	42 660	24	117
9 to 10	26	142	160	5.5	910 300	35 010	17	96
10 to 11	31	156	191	5.0	1 686 000	54 390	30	149
11 to 12	29	135	202	4.7	1 133 400	39 080	23	107
12 to 13	8	40	55	5.0	471 000	58 870	32	161
13 to 14	9	42	67	4.7	418 400	46 480	27	127
14 to 15	8	50	61	6.2	302 500	37 810	17	104
15 to 16	16	57	104	3.6	762 500	47 660	36	130

TABLE 14 (*Continued*).

MEMORANDA OF AN INVESTIGATION OF 390 TYPICAL WATER SERVICES AT PITTSBURGH, PA.

Flat Rate. Dollars.	Services Investigated.	No. of Persons.	No. of Rooms.	Av. No. of Persons per Service.	Total Gallons Water used Yearly.	Average Gallons per		
						Service per Year.	Person per Day.	Service per Day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$16 to $17	17	64	122	3.8	706 800	41 580	30	114
17 to 18	15	72	129	4.8	771 700	51 450	29	141
18 to 19	12	65	101	5.4	889 400	74 120	38	203
19 to 20	13	57	108	4.4	581 200	44 710	28	123
20 to 21	13	51	111	3.9	1 079 500	83 040	58	228
21 to 22	18	87	161	4.8	1 378 000	76 550	44	210
22 to 23	15	83	157	5.5	1 364 000	90 930	45	249
23 to 24	11	65	106	5.9	947 600	86 150	40	236
24 to 25	13	70	125	5.4	814 500	62 660	32	172
25 to 26	8	36	66	4.5	409 000	51 120	31	140
26 to 27	15	84	119	5.6	1 359 600	90 640	44	248
27 to 28	13	73	91	5.6	1 197 000	92 080	45	252
28 to 29	8	41	73	5.1	569 000	71 130	38	195
29 to 30	6	37	46	6.2	508 200	84 700	37	232
30 to 31	4	23	38	5.7	437 200	109 300	52	299
31 to 32	8	41	89	5.1	880 000	110 000	59	302
32 to 33	5	21	55	4.2	614 200	122 840	80	336
33 to 34	2	12	24	6.0	200 500	100 250	46	275
34 to 35	8	38	83	4.7	861 500	107 690	63	295
35 to 36	2	9	18	4.5	179 100	89 550	55	245
36 to 37	2	8	20	4.0	260 500	130 250	89	357
38 to 39	1	5	11	5.0	90 400	90 400	50	248
39 to 40	1	6	12	6.0	226 100	226 100	103	619
40 to 41	3	22	31	7.3	450 100	150 030	56	410
41 to 42	1	4	14	4.0	132 700	132 700	91	364
42 to 43	1	4	13	4.0	91 900	91 900	63	252

TABLE 14 (*Continued*).

MEMORANDA OF AN INVESTIGATION OF 390 TYPICAL WATER SERVICES AT PITTSBURGH, PA.

Flat Rate. Dollars.	Services Investigated.	No. of Persons.	No. of Rooms.	Av. No. of Persons per Service.	Total Gallons Water used Yearly.	Average Gallons per		
						Service per Year.	Person per Day.	Service per Day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$48 to $49	1	7	8	7.0	77 200	77 200	30	212
51 to 52	1	4	10	4.0	188 400	188 400	129	516
59 to 60	1	4	12	4.0	231 700	231 700	159	635
80 to 81	1	13	26	13.0	468 700	486 700	102	1 332
86 to 87	1	3	20	3.0	65 600	65 600	60	180
97 to 98	1	5	13	5.0	84 700	84 700	46	232
	390	1 931	3 071	5.0	25 303 900	64 900	35	178

Floor Area as a Basis for Estimating Water Consumption.

W. W. Brush, in charge of the design of the delivery system to carry the Catskill water to the five boroughs of New York, found the per capita basis of estimating water consumption to be very uncertain in some parts of New York City.

Various gagings of the consumption in different classes of buildings are shown in the following tables taken from his paper.

TABLE 15. Consumption of Water in Various Classes of Buildings in New York City.

(From *Engineering News*, June 13, 1912, page 1132.)

No. of District.	Characteristics of Occupancy.	Consumption. Mgd.	Population, Resident.	Consumption per Capita. Gal.
	Gagings in 1902–03.			
1	Large hotels, high-class residences....	1.87	8 396	223
2	East Side tenements................	1.44	38 906	37
3	East Side tenements................	5.40	90 000	60
6	Residence and high-class apartments..	0.76	10 164	75
8	Business, office buildings, waterfront, shipping......................	9.45	11 000	860
9	High-class apartments and hotels.....	1.37	8 872	154
10*	East Side tenements, some waterfront.	20.20	218 023	93
11	Uptown residences and medium-class apartments.....................	4.89	4 380	112
12	Upper East Side tenement, waterfront, power houses, and breweries	2.75	39 969	69
	Gagings in 1911.			
1a	East Side tenement, some waterfront (same as district No. 10)..........	11.44	230 500	50
2a	All classes.........................	29.48	204 557	144
3a	High-class apartments and residences..	22.18	186 990	118
4a	High-class apartments, residences, and tenements....................	12.74	138 800	92
5a	East Side tenement and waterfront....	8.28	84 580	98
6a	High-class apartments, residences, tenements, and waterfront	14.82	173 000	86
7a	All classes.........................	13.38	169 100	79
8a	All classes.........................	13.66	209 393	65

* An error was later discovered in the measurement of flow in this district, which reduced the consumption as given by about 50 per cent.

It will be seen that on the per capita basis the consumption varied from 37 gal. per capita per day, in certain East Side tenements, to 860 gal. per capita per day in some of the office buildings.

This resulted in the adoption of the floor area basis of water consumption, using a unit of 1 000 sq. ft., for the following reasons:

"The amount of water used in any building is proportional to the size and height of same.

"The total floor area could readily be obtained from available atlases.

"Very large areas, especially in the Borough of Manhattan, are occupied only for business purposes.

"A large and increasing part of the population, especially in the Borough of Manhattan, is transient, and, therefore, cannot be accurately determined for the present nor for the future.

"Several hundred thousand people in Manhattan engaged in business, make their homes in adjoining sections of New York State and New Jersey.

. . . .

"It was found, upon examination, that, with the exception of those buildings where the consumption of water would be unusually high, such as hotels, laundries, ice plants, etc., the use of water per 1 000 ft. of floor area was 150 to 300 gal. per day."

A comparison of a high-class apartment house district and a low-class tenement district gave, on the per capita basis, a consumption of 154 gal. and 37 gal. respectively, while on the basis of 1 000 sq. ft. floor area, the respective consumptions were 181 and 179 gallons.

"While this close agreement in consumption for the two districts was a coincidence, it strikingly illustrated the uniformity obtained from the floor-area basis as compared with the per capita basis, in two residential districts where the character of population varied widely."

As a result of this study, the following assumptions were decided upon:

TABLE 16. Assumed Future Water Consumption in New York City.
(*Engineering News*, June 13, 1912, page 1132.)

Section.	Average Height of Building, Stories.	Percentage of Block Built Upon.	Consumption per 1 000 sq. ft. of Floor Area, Gal. Daily.
South of 23d Street	8	85	350
23d to 46th Street	10	85	350
49th to 59th Street	8	85	350
59th Street to Spuyten Duyvil	6	75	300

The Effect of the Introduction of Sewers upon Water Consumption in any community is indicated by the experience in Marlborough, Newton, and Waltham, Mass., shown in Table 17, and by similar figures for residences, with and without sewer connections, located in Madison, Wis.

TABLE 17.

AVERAGE CONSUMPTION OF WATER IN THREE MASSACHUSETTS CITIES BEFORE AND AFTER THE INTRODUCTION OF A FAIRLY COMPLETE SYSTEM OF SEWERS.

(By courtesy of X. H. Goodnough, Chief Engineer, Massachusetts State Board of Health.)

City.	Gallons per Person per Day.																	
	Years Previous to Introduction of Sewers.							Year when System of Sewers was Practically Completed. (1891.)	Years Subsequent to Introduction of Sewers.									
	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	19
Marlborough........	13	17	20	21	24	24	25	26	30	30	35	34	37	37	38	38	36	37
Newton............	28	31	33	33	31	36	40	43	50	52	60	65	63	60	57	63	62	63
Waltham..........	37	36	39	33	31	32	33	40	47	53	61	59	71	70	76	88	90	88

TABLE 18.

CONSUMPTION OF WATER IN MADISON, WIS., IN RESIDENCES WITHOUT AND WITH SEWER CONNECTIONS.

(By courtesy of Mr. Frank A. Newton.)

No. of Services.	Total Consumption. Cubic Feet per Year.	Average Consumption. Gallons per Day per Service.
Residences without Sewer Connections.		
23	8 444	7.5
33	21 960	13.7
5	5 544	22.8
2	3 346	34.4
1	2 300	47.3
1	2 977	61.2
65	44 571	
Average................	685.8*	14.1
Residences with Sewer Connections.		
2 634	3 788*	68.0

* Average per service.

The Effect upon Domestic Consumption of the Installation of Meters is interestingly shown by the following diagrams, Figs. 1, 2, and 3, prepared by Metcalf & Eddy for the report of the Sewage Disposal Commission of Milwaukee, 1910.

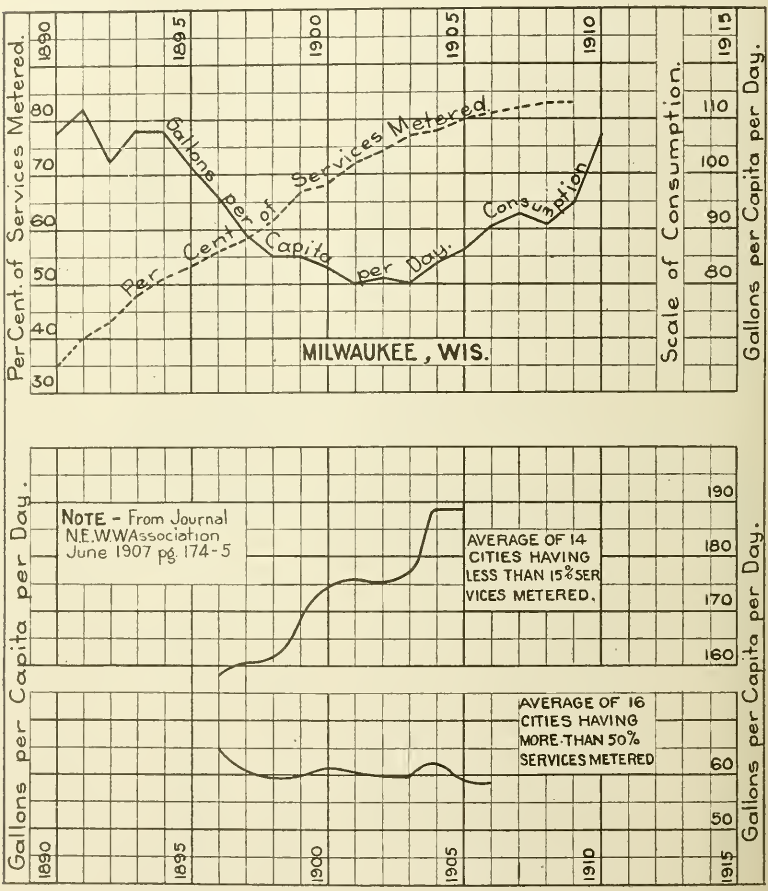


Fig. 1.

Water Consumption in Various Cities.

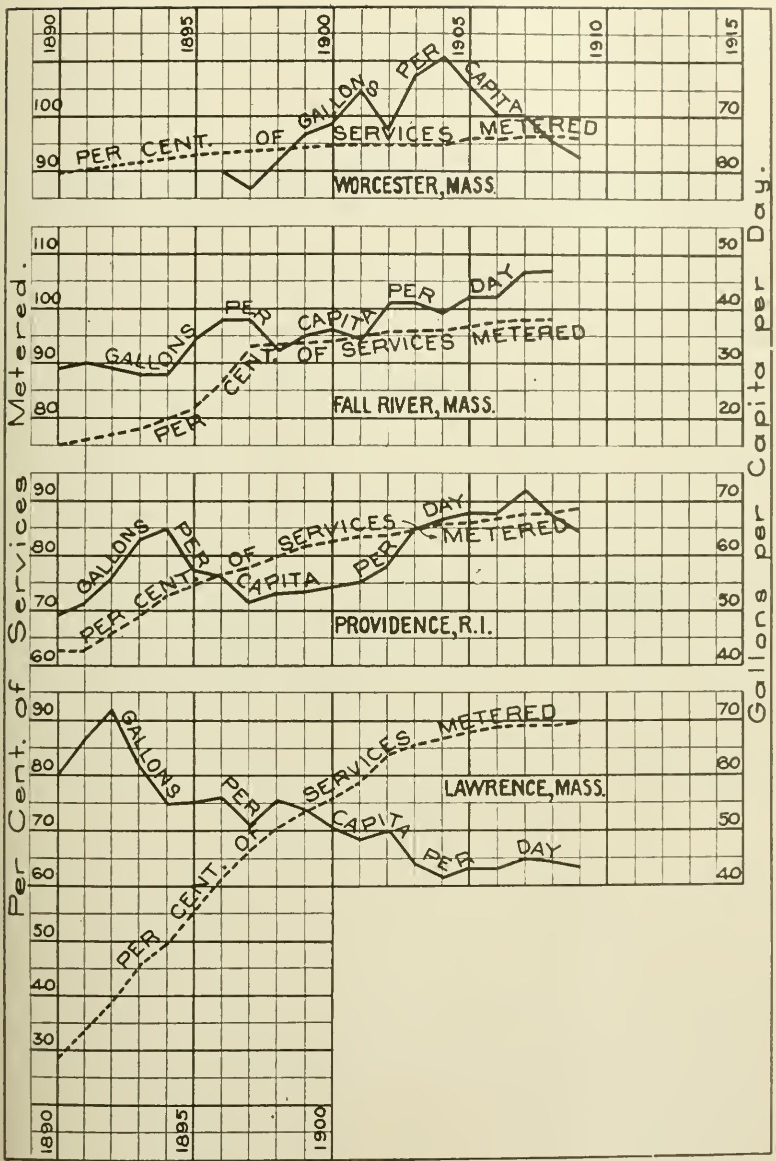


FIG. 2.

WATER CONSUMPTION IN VARIOUS CITIES.

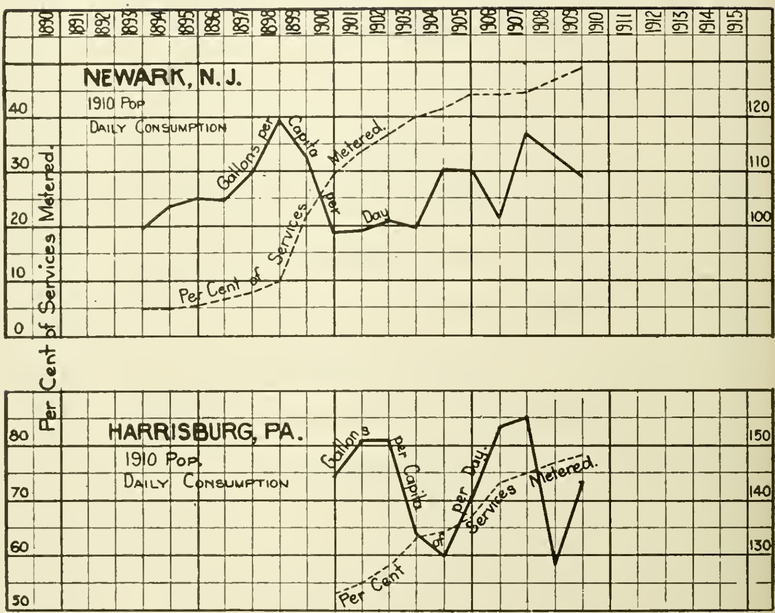


Fig. 3.

Water Consumption in Various Cities.

Mr. William S. Johnson, in a valuable paper upon water consumption,* quoted the following per capita consumption statistics for the year 1905:

TABLE 19.

AVERAGE PER CAPITA CONSUMPTION OF WATER, 1905.

(Cities in United States larger than 25 000 population.)	
34 cities, not over 10 per cent. of taps metered,	146 gal. per day.
23 cities, 10 to 25 per cent. of taps metered,	97 gal. per day.
18 cities, 25 to 50 per cent. of taps metered,	89 gal. per day.
14 cities, 50 to 75 per cent. of taps metered,	89 gal. per day.
19 cities, more than 75 per cent. of taps metered,	72 gal. per day.
(Cities and towns in United States smaller than 25 000 population.)	
26 places, not over 25 per cent. of taps metered,	77 gal. per day.
12 places, 25 to 50 per cent. of taps metered,	63 gal. per day.
9 places, 50 to 75 per cent. of taps metered,	45 gal. per day.
22 places, over 75 per cent. of taps metered,	48 gal. per day.

NUMBER OF CONSUMERS ON MINIMUM RATE, AND NUMBERS PAYING DIFFERENT RATES.

One of the most difficult matters to forecast in the operation of a new rate schedule — particularly in passing from a flat rate to a meter schedule — is the number of consumers which will fall within the class of minimum rate payers, though fortunately the disastrous effect of erroneous assumptions in this direction may be offset by the maintenance, temporarily at least, of a high annual minimum charge. This difficulty is clearly indicated by Table 20, showing the variation found in different communities in the percentage of consumers who are minimum rate payers.

*JOURNAL N. E. W. W. A., Vol. 21, page 109.

TABLE 20.

DATA RELATING TO CHARGES FOR METERED WATER.

(Condensed from Report of the New England Water Works Association Committee on Meter Rates, presented September 13, 1905.)*

No.	City or Town.	Total Number of Services.	Number of Metered Services.	Percentage of Metered Services.	Minimum Annual Meter Charge, in Dollars.	Amount of Water Allowed for Minimum Charge.	Number of Services using Less than This Allowance.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Atlantic City, N. J.	4 636	3 943	85	.....	....	3 159
2	Attleboro, Mass.	....	1 567	100	$6.00	2 600 cu. ft.	406
3	Bath, Me.	2 060	105	5	20.00	8 000 cu. ft.	65
5	Billerica, Mass.	264	142	54	12.00	40 000 gal.	71
7	Bristol, Conn.	1 250	44	4	25.00	8 330 gal.	7 or 8
8	Brockton, Mass.	5 849	5 299	91	8.00	27 000 gal.	......
9	Burlington, Vt.	3 524	2 680	76	6.00	4 000 cu. ft.	About 1 100
10	Claremont, N. H.	822	152	19	12.00	60 000 gal.	10
11	Cleveland, Ohio	60 627	30 226	49	2.50	47 000 gal.	11 000
12	Clinton, Mass.	1 743	1 417	82	6.00	2 400 cu. ft.	About 225
13	Concord, N. H.	3 376	1 272	38	2.50	1 700 cu. ft. per quar.	597
15	Des Moines, Ia.	9 509	6 500	68	4.00	150 cu. ft. per mo.	775
16	Detroit, Mich.	61 465	5 847	10	1.75 per quar.	30 000 gal.	......
17	E. Providence, R. I.	993	686	69	10.00	33 333 gal.	400
18	Fairhaven, Mass.	600	200	33	10.00	33 000 gal.	......
19	Fitchburg, Mass.	4 695	2 712	58	10.00	....	1 000
20	Gloucester, Mass.	3 490	160	5	2.00	67 000 gal.	......
21	Gloversville, N. Y.	3 186	300	9	4.00	....	Very few
22	Greensburg, Pa.	2 424	2 656	100	12.00	20 000 gal.	......
23	Hartford, Conn.	10 000	9 600	96	5.00	....	......
24	Haverhill, Mass.	5 650	662	12	10.00	128 gal. per day	Four fifths
26	Indianapolis, Ind.	14 240	900	6	16.20	7 500 gal. per mo.	......
27	Jacksonville, Fla.	3 270	1 706	52	8 and 12	300 gal. per day	......

28	Kewanee, Ill.	600	600	100	5.00	1 700 cu. ft. per year	se 33⅓ per cent.
29	Knoxville, Tenn.	5 660	1 677	30	10.00	33 000 to 40 000 gal. per year	. . . . . .
30	Leominster, Mass.	2 353	711	30	10.00	5 000 cu. ft.	. . . . . .
31	Manchester, N. H.	6 000	4 000	67	10.00	8 000 cu. ft.	300
32	Marion, Ohio	891	653	73	2.50 per quar.	10 000 gal. per quar.	About 60 per cent.
33	Marlboro, Mass.	2 258	1 266	56	6.00	1 777 cu. ft.	. . . . . .
34	Milton	1 173	1 173	100	8 and 16	2 400 & 4 800 cu. ft.	. . . . . .
35	Montclair, N. J.	2 650	2 650	100	10.00	4 445 cu. ft.	About ⅓
37	Muscatine, Ia.	1 240	100	8	10.00	25 000 gal.	None
38	Nashua, N. H.	†4 000	657	16	16.00	80 000 gal.	. . . . . .
39	New Bedford, Mass. . .	9 927	1 954	19	5.00	33 333 gal.	Quite a number
40	New London, Conn. . . .	3 463	278	8	10.00	33 333 gal.	Few
41	Newton, Mass.	7 404	6 367	86	10.00	28 571 gal. and up	About 40 per cent.
43	Oberlin, Ohio	700	512	73	5.00	2 240 cu. ft.	About 100
44	Paterson, N. J.	11 735	3 054	26	12.00	1 300 cu. ft. per quar.	About 60 per cent.
45	Portland, Conn.	550	30	6	15.00	60 000 gal.	None
46	Portland, Ore.	19 473	750	4	Fixture rate	Quantity paid for by schedule rate	About ½
47	Quincy, Mass.	5 327	165	3	18 per year	60 000 gal.	75 per cent.
48	Reading, Mass.	1 162	1 035	89	6 per year	16 000 gal.	604
50	Rockville, Conn.	. . . .	239	. . .	6.00	25 000 gal.	. . . . . .
52	Somerville, Mass.	11 059	1 537	14	1.50 per quar.	1 250 cu. ft.	Few
55	Stapleton, N. Y.	3 267	1 500	46	$2.50 per quar.	740 cu. ft. per quar.	About ½ per cent.
56	Syracuse, N. Y.	18 988	10 063	53	5.00	3 600 cu. ft. per an.	5 000
57	Tarrytown, N. Y.	700	678	96	1 per quar.	333 cu. ft.	95
58	Taunton, Mass.	4 753	2 134	45	10.00	40 000 gal.	900
59	Waterbury, Conn.	5 388	518	10	5.00	17 000 gal.	10
61	Watertown, Mass.	1 730	1 595	92	10.00	4 000 cu. ft.	656
62	Wellesley, Mass.	916	911	99	6.00	16 000 gal.	300
63	Westboro, Mass.	648	630	97	5.00	16 724 gal. per an.	225

* See Journal N. E. W. W. A., Vol. 19, p. 334.

† About.

TABLE 20 (*Continued*).

DATA RELATING TO CHARGES FOR METERED WATER.

No.	City or Town.	Total Number of Services.	Number of Metered Services.	Percentage of Metered Services.	Minimum Annual Meter Charge in Dollars.	Amount of Water Allowed for Minimum Charge.	Number of Services using Less than This Allowance.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
64	Westerly, R. I.	1 375	1 088	80	$10.00	33 333⅓ gal. per an.	767
65	Whitman, Mass.	1 058	5 010	47	6.00	30¢ per 1 000 gal.	¼ (perhaps)
66	Winooski, Vt.	282	254	90	2 per quar.	1 000 cu. ft.	119
68	Woonsocket, R. I.	2 557	2 251	88	10.00	33 333 gal.	893
69	Worcester, Mass.	14 129	13 386	95	4.00	16 000 gal. per an.	Quite a large number
72	York, Pa.	10 060	293	3	1 per mo.	3 333 gal. per mo.	66

NOTE. Cities omitted are those for which the data, under the headings here used, were incomplete.

Further data along this line, relating to cities and towns in Wisconsin, have been furnished by Mr. Frank A. Newton, formerly assistant statistician of the Wisconsin Railroad Commission (1912).

TABLE 21.

WATER CONSUMPTION DATA.

(By courtesy of Mr. Frank A. Newton, Assistant Statistician, Wisconsin Railroad Commission, April, 1912.)

Distribution of Sales. Per Cent.

Cu. Ft.	Superior.	Marshfield.*	Richland Center.	Evansville.
1st 1 000	39.2	7.3	40.2	54.1
Next 2 000	11.7	6.4	36.0	23.0
Next 7 000	12.3	7.4	20.5	19.6
1st 10 000	63.2	21.1	96.7	96.7
Next 15 000	10.3	6.5		
Next 25 000	9.4	6.2		
Next 50 000		8.1	3.3	3.3
Next 100 000	17.1	12.8		
Over 200 000		45.3		

Milwaukee Water Consumers.

(Single Residences.)

11 765 consumers used less than 600 cu. ft. during some quarters. Consumption for year by this class = 34 787 400 cu. ft.

Average: 2 957 cu. ft. per consumer per year.

Average: 7.1 cu. ft. per consumer per day.

Average: 53.3 gal. per consumer per day.

Consumers using more than 600 cu. ft. every quarter, — second quarter:

4 432	— under 1 000 cu. ft.	3 725 600
16 884	— 1 000 to 5 000	35 021 600
851	— 5 000 to 25 000	6 935 600
44	— 25 000 to 100 000	2 124 200
6	— over 100 000	1 637 200
22 217		49 444 200

2 225 cu. ft. per consumer per quarter.

24.7 cu. ft. per consumer per day.

185.3 gal. per consumer per day.

* The Marshfield record is misleading by reason of one or two very large consumers. When correction is made for these consumers the percentage closely approximates those given for the other cities named.

Fourth quarter:

6 036	— under 1 000	4 645 600
15 403	— 1 000 to 5 000	49 407 900
756	— 5 000 to 25 000	6 239 200
42	— 25 000 to 100 000	1 837 200
7	— over 100 000	2 001 700
22 244		64 131 600

2 882 cu. ft. per consumer per quarter.
32 cu. ft. per consumer per day.
240 gal. per consumer per day.

49 444 200	
64 131 600	
113 575 800	
2	
227 151 600	11 765
34 787 000	22 220

261 938 600 = 33 985 cons. = 7 707 cu. ft. per consumer per year.
21.1 cu. ft. per consumer per day. 158.3 gal. per consumer per day.

TABLE 22.

WATER CONSUMPTION DATA FOR JEFFERSON, WIS.

(From Reports Wisconsin Railroad Commission, 1910, Vol. 74, Jefferson, Wis., Municipal Light and Water Plant, p. 580.)

Residence Consumers.

Cu. Ft. per Year per Service.	No. of Services.	Gal. per Day per Service.
300 to 400	1	7.2 ± 14 per cent.
400 to 500	4	9.3 ± 11 per cent.
500 to 600	3	11.3 ± 9 per cent.
600 to 700	3	13.4 ± 8 per cent.
700 to 800	12	15.4 ± 7 per cent.
800 to 900	4	17.5 ± 6 per cent.
900 to 1 000	9	19.6 ± 5 per cent.
1 000 to 1 100	4	21.6 ± 5 per cent.
1 100 to 1 200	5	23.6 ± 4 per cent.
1 200 to 1 300	6	25.7 ± 4 per cent.
1 300 to 1 400	6	27.8 ± 4 per cent.
1 400 to 1 500	5	29.8 ± 3 per cent.
1 500 to 1 600	4	31.9 ± 3 per cent.
1 600 to 1 700	3	33.9 ± 3 per cent.
1 700 to 1 800	2	36.0 ± 3 per cent.
1 800 to 1 900	4	38.2 ± 3 per cent.
1 900 to 2 000	9	40.2 ± 3 per cent.
2 000 to 3 000	46	51.4 ± 2 per cent.
3 000 to 4 000	29	72.1 ± 1 per cent.
4 000 to 5 000	17	92.5 ± 1 per cent.
5 000 to 6 000	11	113.0 ± 1 per cent.
6 000 to 7 000	5	133.9 ± 1 per cent.
7 000 to 8 000	4	154.4 ± 1 per cent.
8 000 to 9 000	1	175.0 ± 1 per cent.
9 000 to 10 000	1	195.5 ± 1 per cent.
over 10 000	2	200.6
	200	

Weighted average, 58.2

In this connection reference may also be had to an interesting description by Mr. J. Herbert Shedd, published in the JOURNAL of this Association, March, 1904, of conditions prevailing in Providence, R. I., in the year 1888.

Similar conditions are found in the works purveying water upon flat-rate bases, as is indicated by the amount paid per annum by different classes of houses. Thus a recent publication by the Water Bureau of Philadelphia in "Water Educational Series," booklet No. 2, February, 1912, gives the following subdivision of total water received for the year 1911.

TABLE 23.

Classification of Philadelphia's Water Revenue Accounts by Amounts.

(From Water Supply Educational Series, Booklet No. 2.)

A. Total water receipts from all sources for 1911		$4 800 000
which were divided approximately as follows:		
From residences	$3 100 000	
From industries and other large consumers	1 400 000	
From miscellaneous (mostly pipe frontage)	300 000	
		$4 800 000
B. Total water receipts from residences for 1911		$3 100,000
which were divided approximately as follows:		
2 500 accounts from $17.00 to $100.00	$100 000	
20 000 accounts at 16.00 each	320 000	
7 000 accounts at 15.00 each	105 000	
18 000 accounts at 14.00 each	252 000	
28 000 accounts at 13.00 each	364 000	
22 000 accounts at 12.00 each	264 000	
20 000 accounts at 11.00 each	220 000	
37 000 accounts at 10.00 each	370 000	
65 000 accounts at 9.00 each	585 000	
24 000 accounts at 8.00 each	192 000	
4 000 accounts at 7.00 each	28 000	
22 000 accounts at 6.00 each	132 000	
29 200 accounts at 5.00 each	146 000	
11 000 accounts at 2.00 each	22 000	
309 700 accounts		$3 100 000
C. Total water receipts from industries (and other large consumers) for 1911		$1 400 000
which were divided approximately as follows:		
60 accounts $2 000 to $50 000	$400 000	
80 accounts 1 000 to 2 000	115 000	
200 accounts 500 to 1 000	125 000	
1 360 accounts 100 to 500	280 000	
13 600 accounts 17 to 100	480 000	
15 300 accounts		$1 400 000

A city in central New York reports the following schedule of flat-rate consumers for the year 1911:

TABLE 24.

CLASSIFICATION OF FLAT-RATE WATER CONSUMERS FOR YEAR 1911, FOR A CITY IN CENTRAL NEW YORK.

(The remaining consumers are on meter schedule.)

No. of Consumers.	Amount Net per Year per Consumer.	No. of Consumers.	Amount Net per Year per Consumer.
1 110.	$5.70	1	$41.16
236	8.56	1	43.08
742	9.50	1	35.44
36	10.45	2	34.50
36	11.40	1	33.88
73	12.36	1	47.80
203	13.32	2	40.84
32	14.28	3	42.12
242	15.20	4	45.60
66	15.80	19	26.60
66	16.16	1	48.00
35	17.12	1	22.60
209	18.04	2	25.96
48	19.00	1	37.36
7	19.60	4	26.90
118	19.96	1	28.50
37	20.88	1	33.84
34	21.88	1	40.20
46	22.16	2	50.00
33	22.80	1	66.50
31	23.76	1	68.40
11	24.08	1	75.00
15	24.72	3	80.00
6	25.00	1	60.00
66	25.32	4	100.00
29	28.16	1	86.48
15	29.12	1	85.00
28	30.04	1	75.36
11	31.36	1	79.80
13	27.56	1	250.00
9	32.32	1	85.80
8	33.32	2	300.00
5	34.30	1	57.47
5	36.12	1	340.00
3	37.08	2	71.24
5	38.00		
		Total 3 741	

TABLE 25.

Classification of Water Consumption, Pennsylvania Water Company. February 21, 1910.

No. of Taps.	Cu. Ft. per Year per Tap.	Total Quantity Cu. Ft. per Year.
6 038	3 344	20 190 000
1 384	5 500	7 612 000
1 795	7 000	12 565 000
1 288	10 000	12 880 000
375	14 000	5 250 000
143	18 000	2 574 000
167	25 000	4 175 000
78	35 000	2 730 000
109	50 000	5 450 000
53	70 000	3 710 000
31	90 000	2 790 000
38	110 000	4 180 000
11 499	7 314	84 106 000
Add: 701	7 314	5 127 000
12 200	7 314	89 233 000

Variation in Rate of Consumption.

monthly fluctuation in consumption.

Mr. William S. Johnson, in an interesting paper entitled "Some New Facts Relating to the Effect of Meters on the Consumption of Water," published in the Journal of this Association, Vol. 21, p. 109, gives the following data concerning the variation in consumption during different months of the year:

DIAGRAM SHOWING DAILY AVERAGE CONSUMPTION OF WATER IN METROPOLITAN WATER DISTRICT DURING EACH WEEK OF THE YEARS 1908, 1909, 1910, 1911 AND 1912.

During this period the percentage of metered services was increased from 5.69 to 51.85 and the population of the District from 972,080 to 1,086,690. The temperature during January and February 1912 was very low.

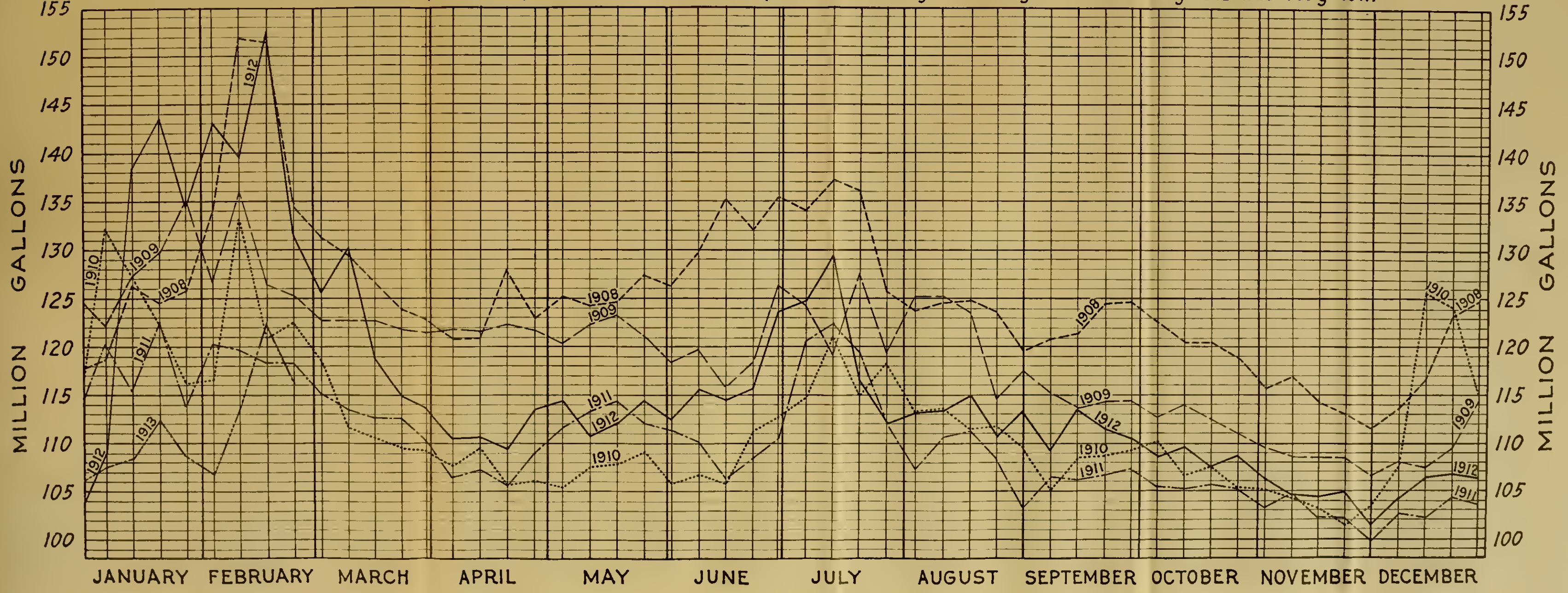


TABLE 26.

Consumption during Different Months.

(Table No. 6, p. 129, Vol. 21, Journal N. E. W. W. A., — Percentage which the consumption during each month is of the average monthly consumption, together with the average rainfall and temperature, Massachusetts.)

Average of Ten Years, 1896–1905.

Month.	Per Cent. of Average Consumption.	Rainfall. Inches.	Temperature. (Degrees fahr.)
January	90	3.68	23.9
February	92	3.98	24.3
March	89	4.77	34.9
April	87	3.86	45.6
May	100	3.18	57.2
June	113	3.60	64.5
July	124	3.85	70.7
August	118	3.97	67.6
September	108	4.12	61.4
October	96	3.35	50.9
November	90	3.34	38.7
December	92	3.74	27.7

(Table No. 8, p. 132, Vol. 21, Journal N. E. W. W. A., — Average consumption of water during each month in 1905 in cities and towns arranged in groups.)

Gallons per Person per Day.

Month.	Boston.	Metropolitan District.	Av. of 23 Suburban Cities and Towns.	Av. of 14 Large Manufacturing Cities.	Av. of 37 Small Cities and Towns.	Av. of 12 Summer Resorts.
January	165	137	77	70	48	67
February	175	147	85	74	53	75
March	152	127	77	69	50	65
April	140	117	73	65	46	65
May	144	121	79	68	52	89
June	146	123	79	70	53	109
July	151	131	88	72	58	150
August	148	127	79	69	56	131
September	147	126	75	65	50	101
October	145	124	73	65	47	74
November	144	122	70	64	46	61
December	153	129	71	64	45	65
Year	151	128	77	68	50	88

HOURLY AND WEEKLY FLUCTUATIONS IN CONSUMPTION.

The following diagrams, prepared by Metcalf & Eddy from data kindly furnished by the superintendents of the works stated, are of interest as showing the hourly and weekly fluctuation in consumption at Holyoke, Springfield, Boston, and Fall River, Mass.; Nashua, N. H.; Hartford, Conn.; Woonsocket, R. I.; and Peoria, Ill.

Further similar data are also contained in this report, in the diagrams relating to waste of water.

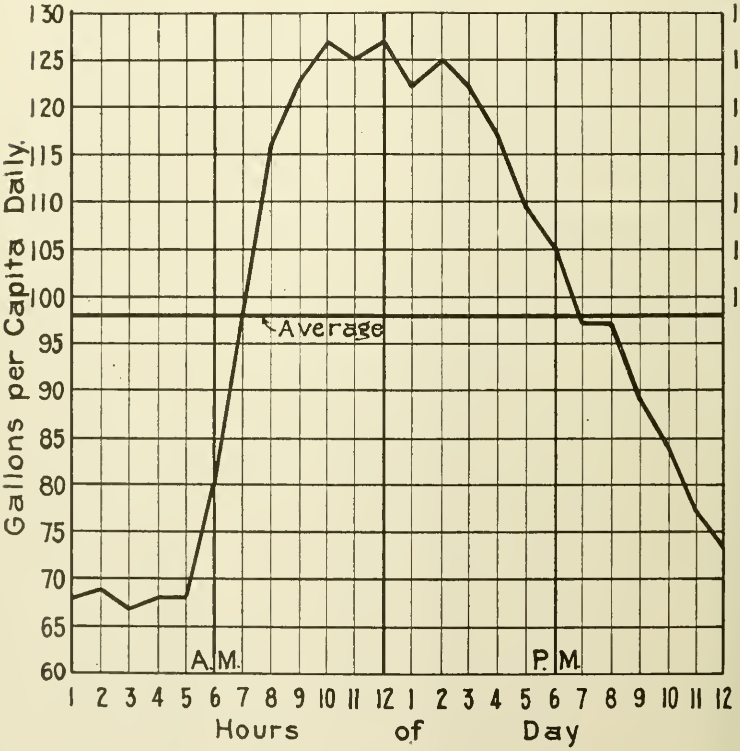


Fig. 4.

Water Consumption in Holyoke, Mass. Hourly Consumption for Average Day in Week ending November 17, 1905. Estimated Population supplied, 51 000.

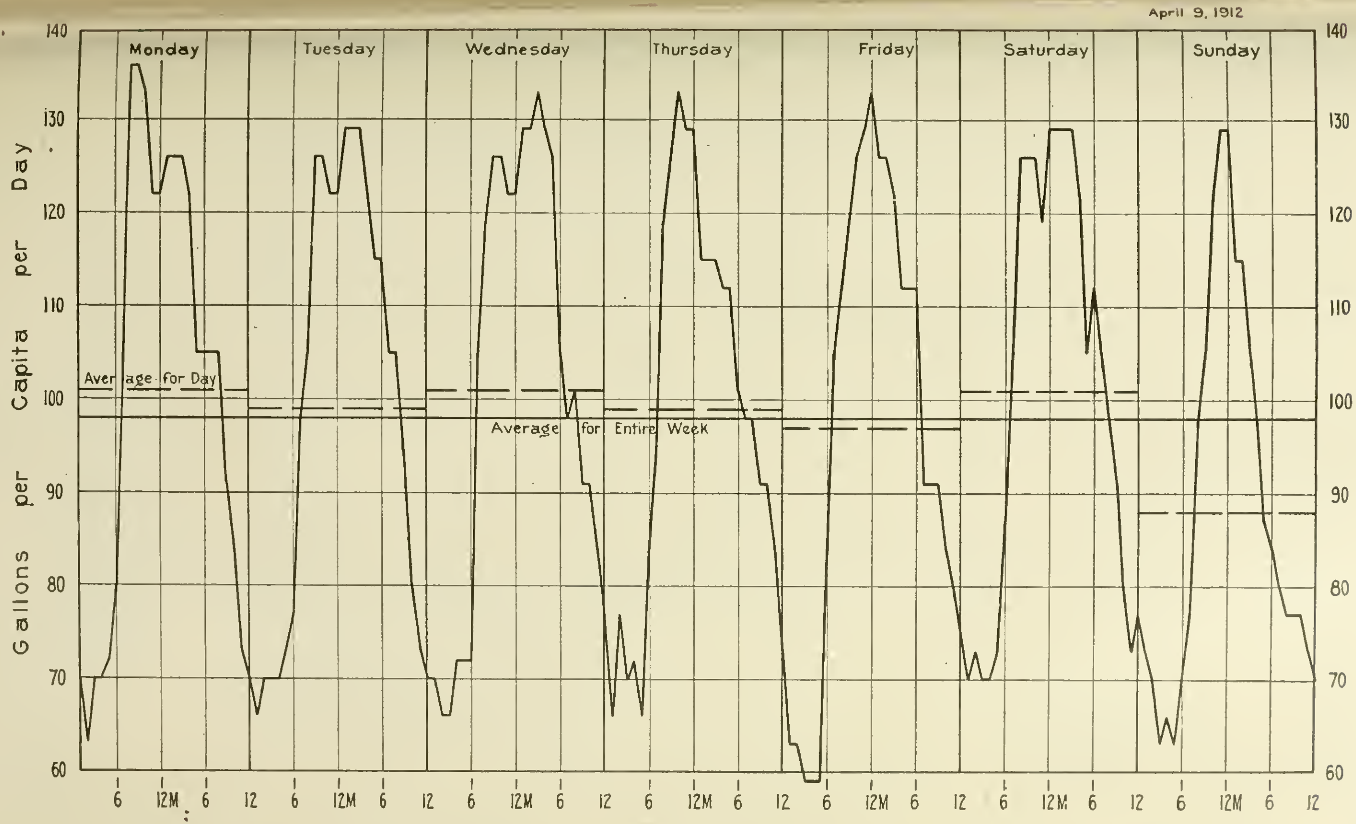


FIG. 5.
HOLYOKE, MASS. FLUCTUATIONS IN WATER CONSUMPTION DURING WEEK ENDING NOVEMBER 17, 1905.

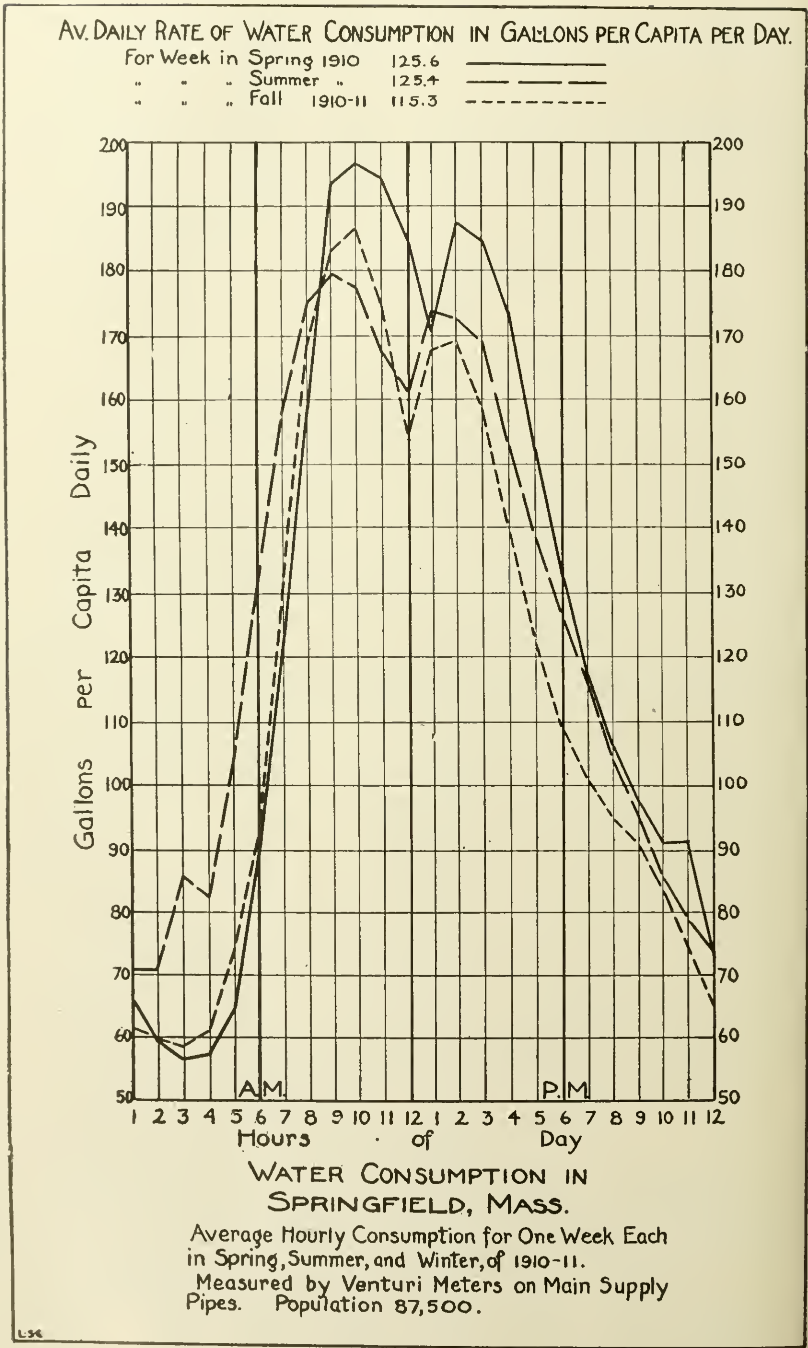

AV. DAILY RATE OF WATER CONSUMPTION IN GALLONS PER CAPITA PER DAY.
For Week in Spring 1910 125.6
" " " Summer " 125.4
" " " Fall 1910-11 115.3
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50
Gallons per Capita Daily
A.M.
P.M.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
Hours of Day
WATER CONSUMPTION IN SPRINGFIELD, MASS.
Average Hourly Consumption for One Week Each in Spring, Summer, and Winter, of 1910-11.
Measured by Venturi Meters on Main Supply Pipes. Population 87,500.

FIG. 6.

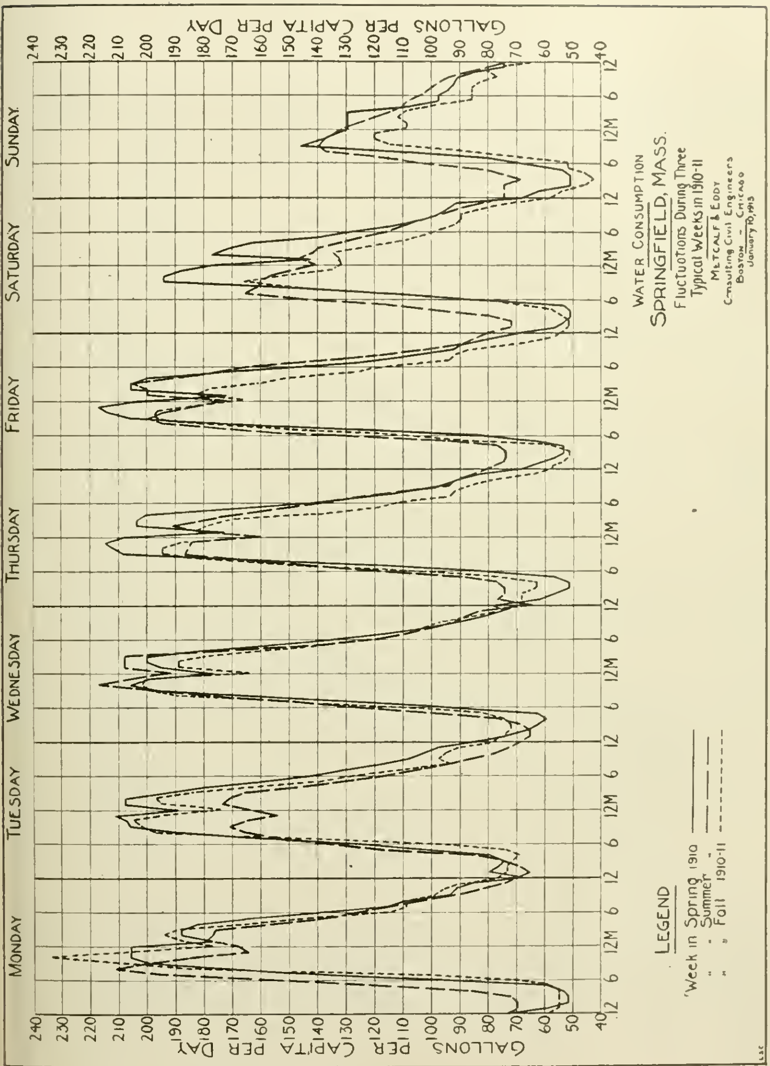

WATER CONSUMPTION
SPRINGFIELD, MASS.
Fluctuations During Three Typical Weeks in 1910-11
METCALF & EDDY
Consulting Civil Engineers
BOSTON — CHICAGO
LEGEND
Week in Spring 1910
" " Summer "
" " Fall 1910-11
GALLONS PER CAPITA PER DAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY

FIG. 7.

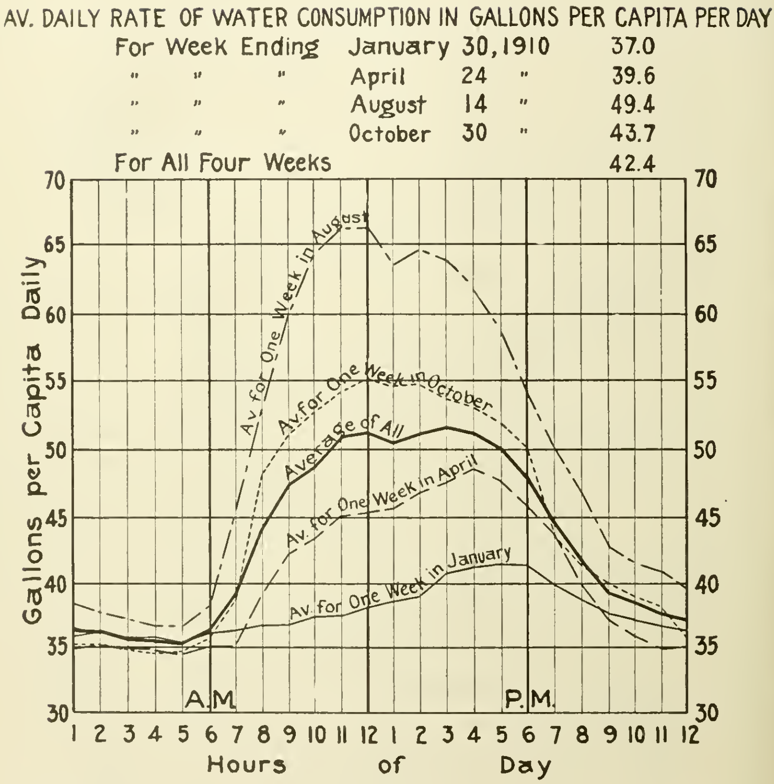


FIG. 8.

WATER CONSUMPTION IN FALL RIVER, MASS. AVERAGE HOURLY CONSUMPTION FOR ONE WEEK EACH IN WINTER, SPRING, SUMMER, AND AUTUMN, 1910. COMPUTED FROM PUMP RECORDS ADJUSTED FOR SLIP AND OVERFLOW FROM STANDPIPE. POPULATION, 119 295 (CENSUS).

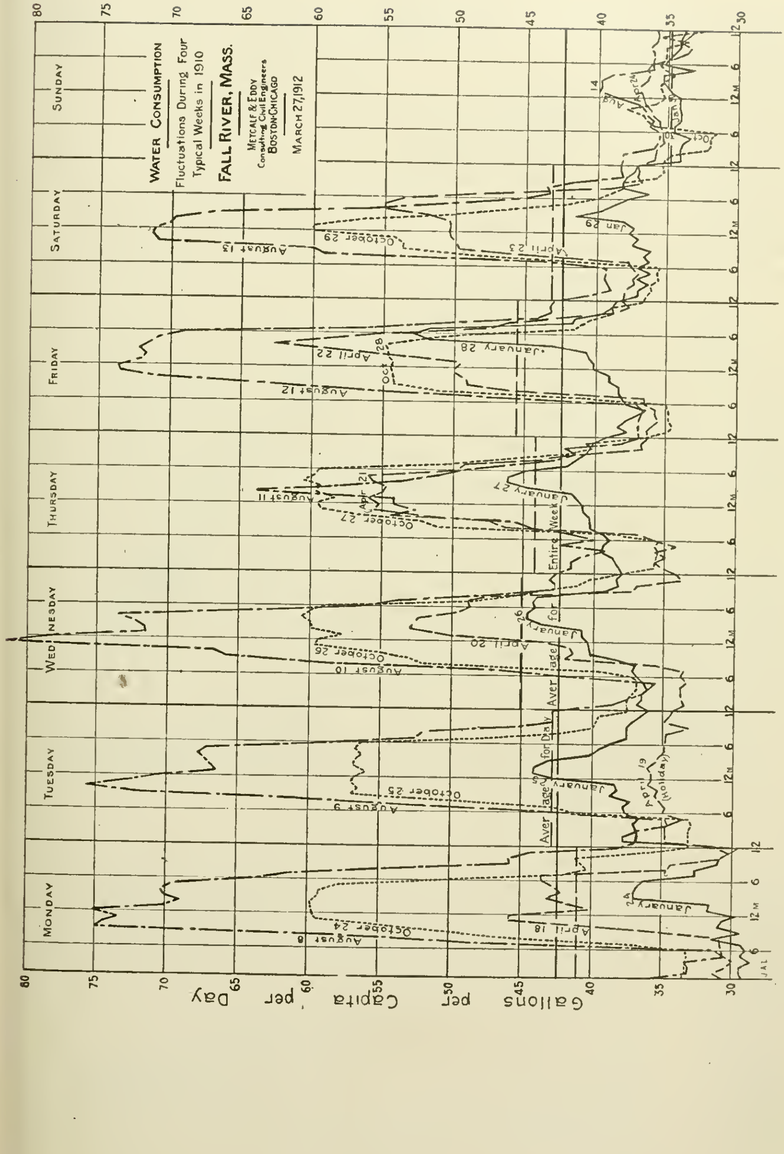

WATER CONSUMPTION
Fluctuations During Four Typical Weeks in 1910
FALL RIVER, MASS.
METCALF & EDDY
Consulting Civil Engineers
BOSTON-CHICAGO
MARCH 27, 1912
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
Gallons per Capita per Day
Average for Day
Average for Entire Week

FIG. 9.

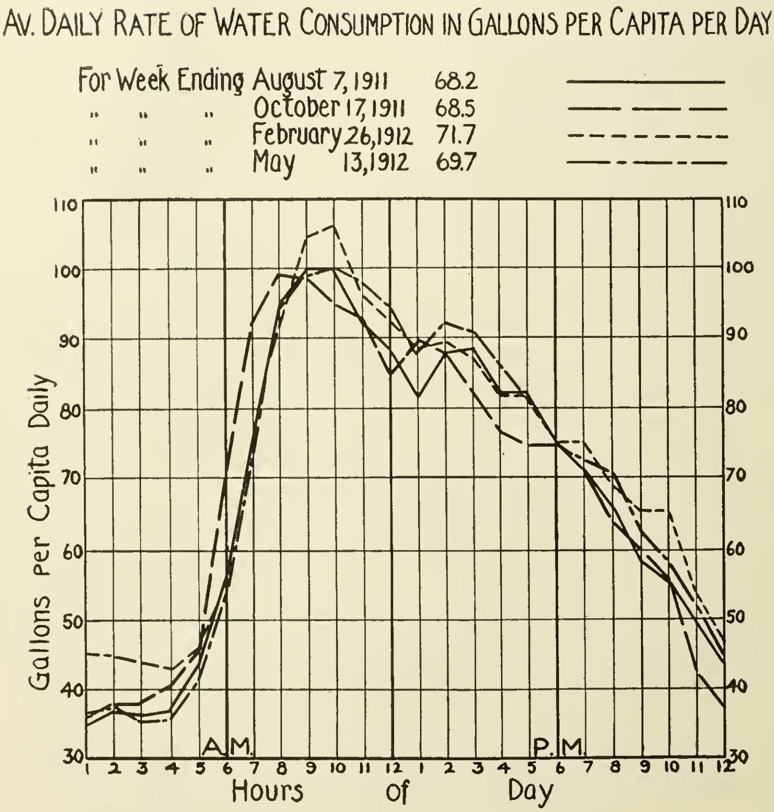


Fig. 10.

Water Consumption in Hartford, Conn. Average Hourly Consumption for one Week each in Summer, Autumn, Winter, and Spring in 1911–12, Measured by Venturi Meter. Population, 121 644.

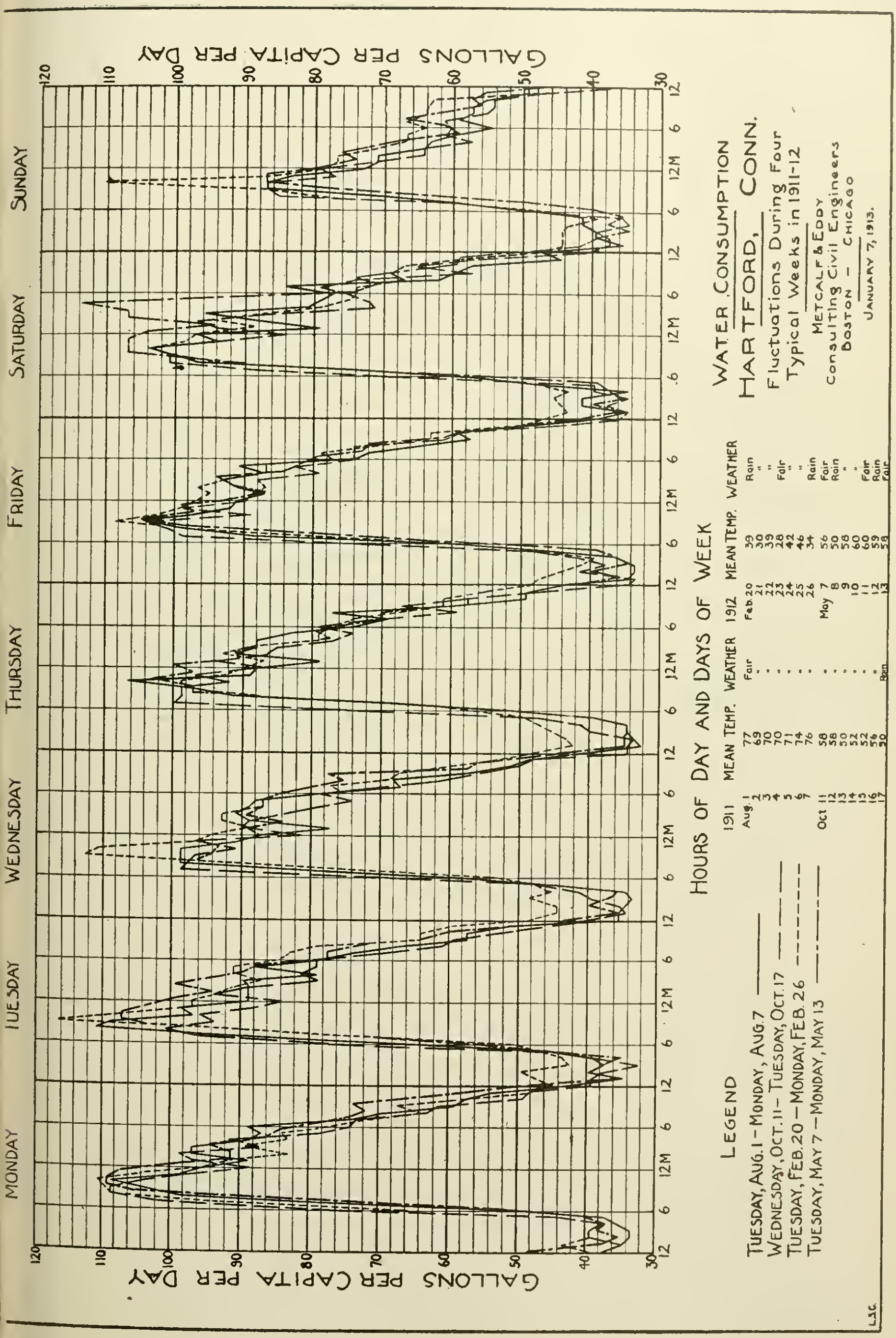

Gallons per Capita per Day
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Hours of Day and Days of Week
Legend
Tuesday, Aug. 1 – Monday, Aug. 7
Wednesday, Oct. 11 – Tuesday, Oct. 17
Tuesday, Feb. 20 – Monday, Feb. 26
Tuesday, May 7 – Monday, May 13
1911 Mean Temp. Weather
1912 Mean Temp. Weather
Water Consumption
Hartford, Conn.
Fluctuations During Four Typical Weeks in 1911-12
Metcalf & Eddy
Consulting Civil Engineers
Boston – Chicago
January 7, 1913.

Fig. 11.

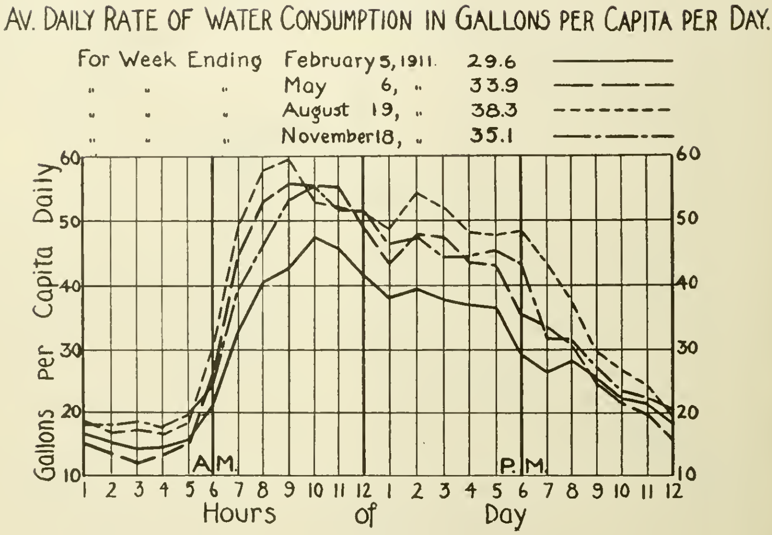


FIG. 12.

WATER CONSUMPTION IN WOONSOCKET, R. I. AVERAGE HOURLY CONSUMPTION FOR ONE WEEK EACH IN WINTER, SPRING, SUMMER, AND FALL OF 1911. MEASURED BY VENTURI METER IN PIPE LINE.

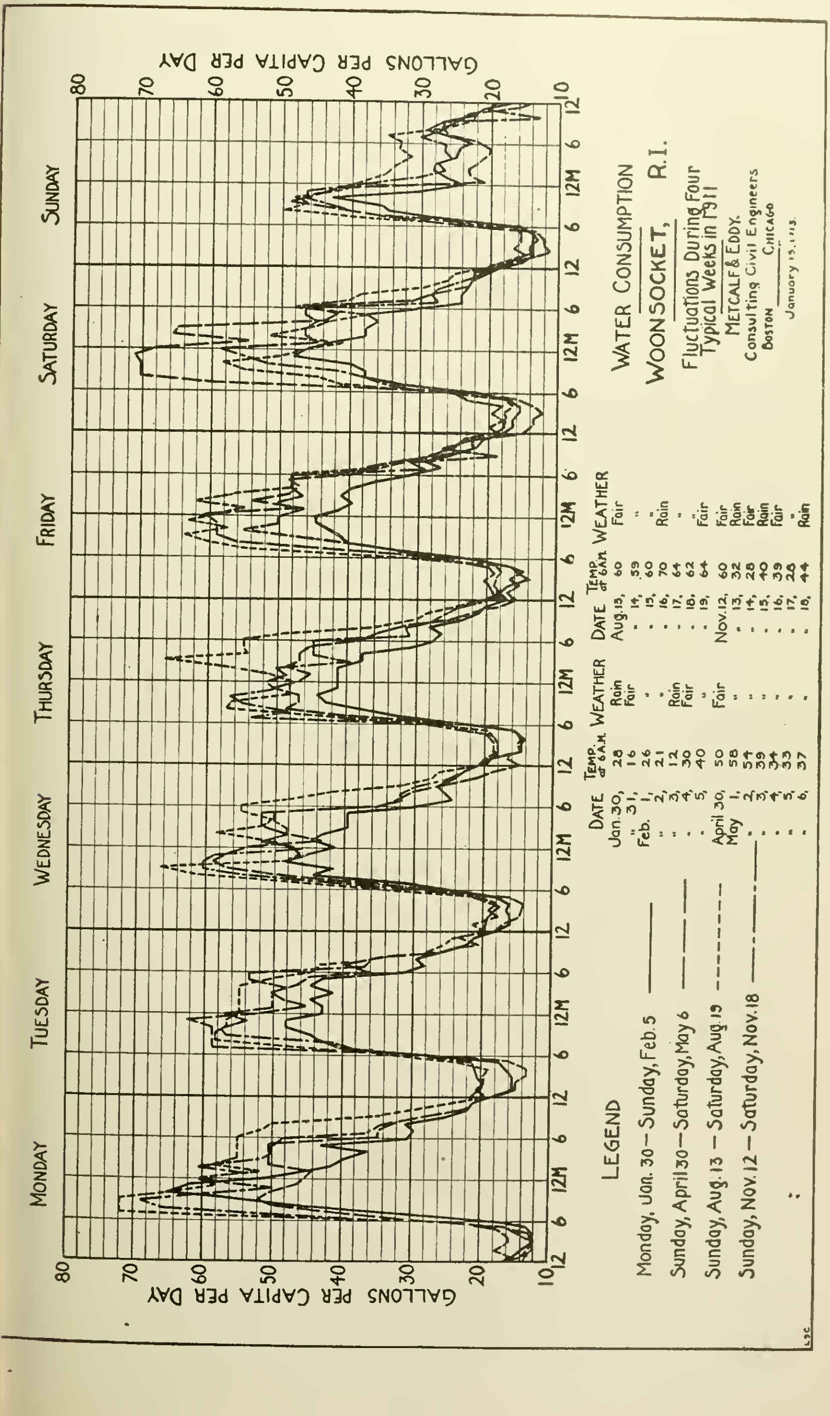

WATER CONSUMPTION
WOONSOCKET, R.I.
Fluctuations During Four Typical Weeks in 1911
METCALF & EDDY.
Consulting Civil Engineers
BOSTON CHICAGO
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
GALLONS PER CAPITA PER DAY
LEGEND
Monday, Jan. 30 — Sunday, Feb. 5
Sunday, April 30 — Saturday, May 6
Sunday, Aug. 13 — Saturday, Aug. 19
Sunday, Nov. 12 — Saturday, Nov. 18
DATE
TEMP. at 6 A.M.
WEATHER

Fig. 13.

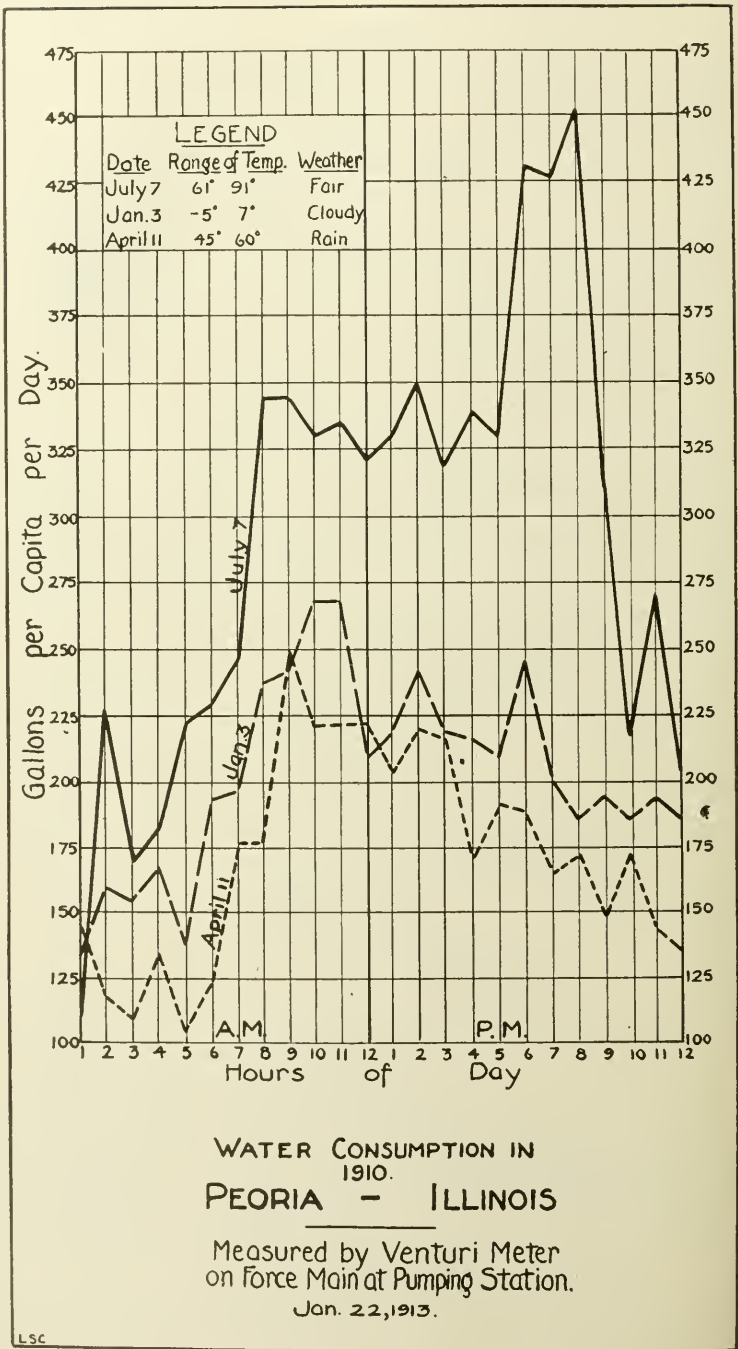

LEGEND
Date Range of Temp. Weather
July 7 61° 91° Fair
Jan. 3 -5° 7° Cloudy
April 11 45° 60° Rain
Gallons per Capita per Day.
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
July 7
Jan. 3
April 11
A.M.
P.M.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
Hours of Day
WATER CONSUMPTION IN 1910.
PEORIA - ILLINOIS
Measured by Venturi Meter on Force Main at Pumping Station.
Jan. 22, 1913.
LSC

FIG. 14.

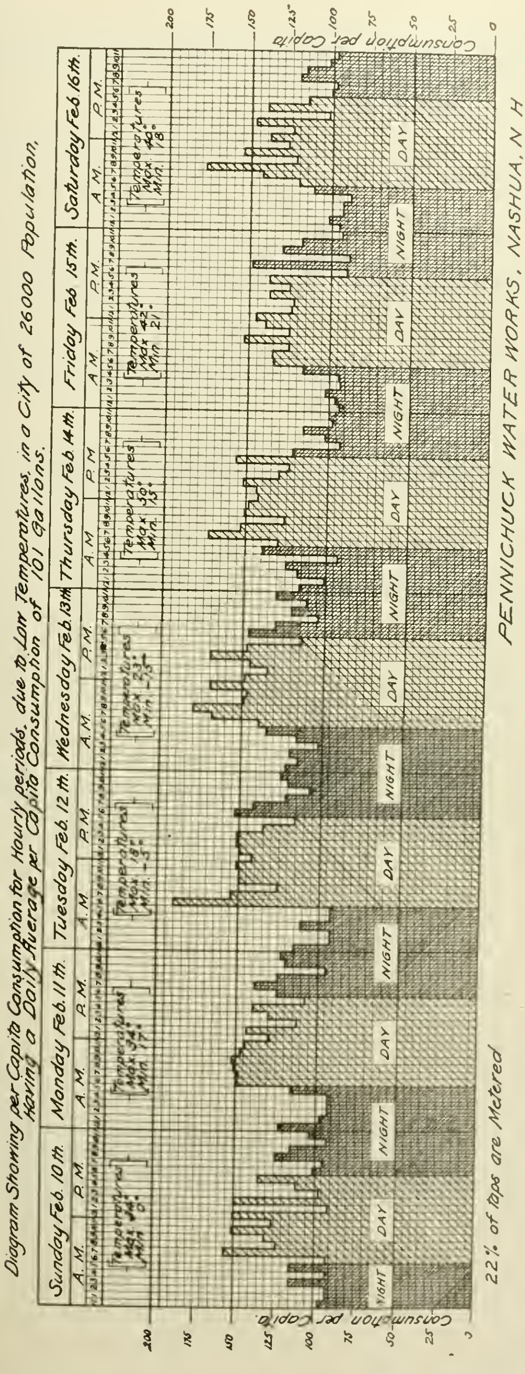


Diagram Showing per Capita Consumption for Hourly periods, due to Low Temperatures, in a City of 26000 Population, Having a Daily Average per Capita Consumption of 101 Gallons.
Sunday Feb. 10th.
Monday Feb. 11th.
Tuesday Feb. 12th.
Wednesday Feb. 13th.
Thursday Feb. 14th.
Friday Feb. 15th.
Saturday Feb. 16th.
A. M.
P. M.
NIGHT
DAY
Consumption per Capita
22% of taps are Metered
PENNICHUCK WATER WORKS, NASHUA, N H

FIG. 15.

TABLE 27.

RECORDS OF MAXIMUM WATER CONSUMPTION FOR MASSACHUSETTS CITIES AND TOWNS, 1910.

(By courtesy of X. H. Goodnough.)

City or Town.	Population.	Average Daily Consumption per Person.	Max. Monthly Consumption.		Max. Weekly Consumption.		Max. Daily Consumption.	
			Gal. per Person per Day.	Per Cent. of Average for Year.	Gal. per Person per Day.	Per Cent. of Average for Year.	Gal. per Person per Day.	Per Cent. of Average for Year.
Abington and Rockland	12 383	45	63	137	70	151	90	197
Amesbury	9 894	44	50	114	51	116	68	155
Andover	7 301	86	99	115	...	...	162	189
Attleborough	16 215	54	62	115	63	116	91	169
Avon	2 013	36	55	153	72	200	102	283
Ayer	2 797	50	64	128	72	144	172	342
Beverly	18 650	91	146	160	191	210	224	246
Braintree	8 066	81	87	107	93	115	108	133
Bridgewater and E. Bridgewater	11 051	22	27	123	29	132	39	177
Brockton	56 878	39	45	115	55	141	69	177
Brookline	27 792	89	103	116	117	132	128	177
Cambridge	104 839	100	106	106	111	111	119	119
Canton	4 797	61	75	123	84	138	97	159
Danvers and Middleton	10 536	89	108	121	136	153	158	178
Dedham	9 284	129	153	119	163	128	182	141
Easton	5 139	24	28	117	38	158	63	263
Fall River	119 295	44	47	107	50	114	54	123
Foxborough	3 863	50	51	102	59	118	75	150
Framingham	12 948	48	58	121	65	137	86	179
Franklin	5 641	61	88	144	96	158	127	208
Gardner	14 699	44	49	111	55	125	108	246
Gloucester	24 398	55	96	156	114	207	130	237
Grafton	5 705	18	22	122	24	133	32	178
Hudson	6 743	49	60	123	65	133	...	...
Ipswich	5 777	42	60	143	84	200	106	253
Lawrence	85 892	45	51	113	60	133	60	133

Lowell	106 294	51	57	112	66	129	75	147
Lynn and Saugus	97 383	72	79	110	87	121	108	150
Manchester	2 673	120	261	217	327	271	363	302
Mansfield	5 183	75	97	129	103	137	276	368
Marblehead	7 338	79	147	186	169	214	187	237
Marlborough	14 579	37	42	114	59	159	80	190
Maynard	6 390	36	39	108	47	130	60	167
Methuen	11 448	38	54	142	67	176	69	182
Middleborough	8 214	42	53	126	65	155	90	214
Milford and Hopedale	15 243	51	60	118	64	125	71	139
Montague and Erving	8 014	66	75	114	70	106	153	232
Nantucket	2 962	67	128	191	154	230	176	263
Natick	9 866	57	70	123	82	144	170	298
Needham	5 026	66	88	133	98	148	119	180
New Bedford	96 652	81	88	109	98	121	106	131
Newburyport	14 949	68	83	122	94	138	121	178
Newton	39 806	63	74	118	82	130	95	150
North Andover	5 529	40	53	132	64	160	78	195
North Attleborough	9 562	52	73	140	82	158	95	183
North Brookfield	3 075	66	81	123	112	170	213	319
Norwood	8 014	63	86	136	86	136	132	211
Orange	5 282	26	34	131	41	158	62	182
Peabody	15 721	168	198	118	182	108	270	161
Plymouth	12 141	103	131	127	140	136	171	166
Provincetown	4 369	38	69	182	77	203	93	245
Randolph and Holbrook	7 117	74	120	162	140	189	175	237
Reading	5 818	35	52	149	60	172	66	189

TABLE 27 (*Continued*).

RECORDS OF MAXIMUM WATER CONSUMPTION FOR MASSACHUSETTS CITIES AND TOWNS, 1910.

City or Town.	Population.	Average Daily Consumption per Person.	Max. Monthly Consumption.		Max. Weekly Consumption.		Max. Daily Consumption.	
			Gal. per Person per Day.	Per Cent. of Average for Year.	Gal. per Person per Day.	Per Cent. of Average for Year.	Gal. per Person per Day.	Per Cent. of Average for Year.
Rockport	4 211	72	148	205	196	272	212	295
Salem	43 697	90	101	112	103	114	133	148
Sharon	2 310	57	97	170	120	210	137	240
Stoughton	6 316	35	43	123	58	166	75	214
Taunton	34 259	63	70	111	74	118	87	138
Wakefield	11 404	61	85	139	107	175	127	208
Walpole	4 892	102	119	117	149	146	252	247
Waltham	27 834	88	95	108	98	111	108	123
Webster	11 509	38	49	129	53	139	72	189
Wellesley	5 413	61	68	111	79	129	112	184
Whitman	7 292	29	42	145	44	152	...	...
Winchendon	5 678	30	35	117	40	133	45	150
Woburn	15 308	139	172	124	190	137	232	167
Worcester	145 986	74	85	115	...	...	103	139
Average		63	81	128	93	147	123	198

MAXIMUM RATE OF CONSUMPTION.

Table 27 gives the maximum rate of water consumption for Massachusetts cities and towns, for the year 1910, kindly furnished by Mr. X. H. Goodnough.

Similar data are given in Table 28, relating to Worcester and Providence, kindly furnished by Mr. F. A. McClure and Mr. Otis F. Clapp.

TABLE 28.

Maximum Rate of Water Consumption for Worcester and Providence.

Year.	Worcester, Mass.		Providence, R. I.	
	Per Cent. which Max. Monthly Consumption is of Average for Year.	Per Cent. which Max. Daily Consumption is of Average for Year.	Per Cent. which Max. Monthly Consumption is of Average for Year.	Per Cent. which Max. Daily Consumption is of Average for Year.
(1)	(2)	(3)	(4)	(5)
1897			107.7	139.7
1898			112.4	143.7
1899			115.2	139.7
1900	113.3	169.	121.8	148.0
1901	114.5	137.4	114.1	147.0
1902	111.8	141.4	113.2	135.5
1903	109.8	135.1	108.2	128.3
1904	105.2	126.2	106.8	138.3
1905	105.8	117.2	114.7	137.5
1906	103.5	130.	106.6	120.
1907	110.9	128.	116.1	137.3
1908	105.5	124.1	109.6	139.3
1909	111.5	137.	119.	136.7
1910	115.24	140.70	112.2	138.5
1911	109.08	127.10		

Mr. George G. Earl, superintendent of the New Orleans water works, reports that their new plant served about 250 000 population in 1911, the per capita daily consumption being about as follows:

Average = 64 gal.
Maximum = 100 gal., or 156 per cent. of the average.
Minimum = 32 gal., or 50 per cent. of the average.

Industrial Uses.

Mr. Dexter Brackett, chief engineer of the Metropolitan Water Works, of Boston, reports the following trade uses of water in the Metropolitan Water District. Table 29 gives the water supplied through meters (only, not by flat rates) for domestic, manufacturing and trade, public and miscellaneous purposes in the year 1908; Table 3, p. 38, the per capita consumption and per cent. of services metered in the cities and towns supplied from the Metropolitan Water Works, 1904 to 1912; Table 30, the water supplied, through meters only, for manufacturing, mechanical, and trade purposes during the year 1908; Table 31, similar figures for the year 1902; Table 32, the detailed data for the year 1908, for a number of the cities in the Metropolitan District, from which the summarized data previously alluded to have been prepared.

TABLE 29.

WATER SUPPLIED THROUGH METERS FOR DOMESTIC, MANUFACTURING AND TRADE, PUBLIC AND MISCELLANEOUS PURPOSES IN THE METROPOLITAN WATER DISTRICT DURING THE YEAR 1908.

NOTE. These quantities are exclusive of water used on flat rates.

(By courtesy of Mr. Dexter Brackett.)

City or Town.	Estimated Population, July 1, 1908.	Miles of Pipe, Jan. 1, 1908.	Number of Services, Jan. 1, 1908.	Per Cent. of Services Metered, Jan. 1, 1908.	Estimated Population on Meter Service.	Domestic per Cap. on Meter Population.	Per Capita Consumption on Total Population.					Total per Cap. Delivered to Mains.	Per Cent. of Total Accounted For.	City or Town.
							Domestic.	Mfg. and Mech.	Public.	Miscellan's.	Total.			
Boston	643 810	745.32	91 142	5.69	53 799	33.0	2.92	27.74	2.05	1.01	33.72	153	22.06	Boston
Chelsea*	32 190	40.32	4 000	33.93	13 937	26.1	11.31	20.84	3.38	0.14	35.67	89	40.01	Chelsea
Everett	31 930	45.02	5 161	2.25	395	33.1	0.41	18.07	0.19	0.01	18.68	83	22.62	Everett
Malden	42 140	83.51	7 055	96.10	37 994	17.6	15.92	6.56	3.45	0.63	26.56	44	59.90	Malden
Medford	21 920	53.73	4 378	13.29	3 559	24.8	4.13	6.55	3.90	1.10	15.68	94	16.62	Medford
Melrose	15 210	46.50	3 429	30.85	4 234	30.2	8.41	2.08	....	1.00	11.49	89	12.92	Melrose
Quincy	31 010	95.38	6 091	24.30	8 391	25.6	6.93	19.12	4.42	0.16	30.63	97	30.99	Quincy
Somerville	74 400	86.76	11 662	29.55	26 234	25.6	9.07	16.63	2.44	0.34	28.48	89	32.16	Somerville
Arlington	10 650	36.23	1 929	43.29	4 404	31.9	13.65	10.56	1.88	0.31	26.40	91	28.95	Arlington
Belmont	5 120	20.28	792	100.00	4 402	20.5	17.63	13.01	2.70	6.00	39.34	71	55.12	Belmont
Lexington	4 780	19.45	730	10.96	373	38.4	3.00	2.08	....	0.46	5.54	77	8.05	Lexington
Milton	7 610	39.53	1 285	100.00	6 000	26.7	21.25	3.07	5.78	0.51	30.61	44	70.24	Milton
Nahant	1 090	16.34	410	21.95	404	68.6	25.42	9.09	2.84	3.00	40.35	70	31.39	Nahant
Revere	16 240	37.77	2 927	5.57	938	36.6	2.11	1.89	0.48	1.08	5.56	78	6.99	Revere
Stoneham	6 820	22.07	1 331	2.25	....	...	....	6.09	....	...	6.09	92	6.63	Stoneham
Swampscott	5 830	18.95	1 307	68.25	2 871	34.7	17.17	3.88	1.31	0.06	22.42	76	25.66	Swampscott
Watertown	12 300	32.28	1 886	100.00	11 299	16.7	15.36	8.92	10.54	0.51	35.33	60	59.36	Watertown
Winthrop	9 030	25.35	2 074	3.38	488	35.3	1.91	1.11	2.89	0.07	5.98	103	5.82	Winthrop
Totals	972 080	1 464.79	147 589	17.71	179 722	26.8	4.95	22.45	2.30	0.84	30.54	129	23.74	Totals

* 1909 used on account of fire in April, 1908.

TABLE

WATER SUPPLIED THROUGH METERS IN THE METROPOLITAN
(By courtesy of

	Boston.	Somerville.	Malden.	Chelsea.*	Everett.	Quincy.	Medford.
Population	643 810	74 400	42 140	32 190	31 930	31 010	21 920
Per cent. services metered	5.69	29.55	96.10	33.93	2.25	24.30	13.29
Per cent. population supplied through meters	8.36	35.26	90.16	43.30	1.24	27.06	16.24
Purposes for Which Used.							
Manufacturing, Mechanical and Trade:							
Bakeries	.079	.033	.015	.225	...	...	...
Breweries and bottling	.875	.078	...	...	.086	...	...
Coal dealers	...	.025	.084	.240	...	...	...
Contractors	.011	.029	.029	...	.088	...	...
Dye works	.024	.174	.050	.066	.018	...	.627
Electric companies	.809	.014	1.242	.064	...	.744	...
Elevators and motors	.586	.065	.119	.009	.011	.010	...
Factories and machine shops	1.833	1.364	1.069	4.812	2.279	11.398	.398
Farms and greenhouses	.037	.028	.089	...	.069	.275	.105
Gas works	.488	...	.955	.011	11.436	.119	...
Hotels	3.059	.174	.052	.104	.063	.147	.080
Iron works	.211	.004	...	.804	...	...	.119
Laundries	.656	.456	.395	.975	.467	.333	.144
Milk depots and creameries	.113	...	...	...	...	...	...
Miscellaneous	.441	...	.022	...	...	.066	...
Offices and stores	6.728	.722	1.678	.922	.224	.955	.480
Oils and chemicals	.041	.026	.234	.029	3.127	...	2.458
Railways	8.439	5.573	.160	3.479	.061	2.726	1.586
Restaurants and saloons	.378	...	...	.297	...	...	...
Rubber works	.052	...	.207	7.769	...	...	...
Shipping, wharves, etc.	.918	...	.003	.638	...	.053	...
Slaughtering	.106	7.209	...	...	...	...	...
Stables	.718	.654	.151	.395	.141	.115	.263
Stone works	.089	...	.004	...	...	2.181	.296
Sugar refineries	1.045	...	...	...	...	...	...
Totals	27.736	16.628	6.558	20.839	18.070	19.122	6.556
Domestic	†2.924	9.070	15.924	11.311	.409	6.927	4.132
Public	†2.050	2.439	3.448	3.381	.189	4.421	3.898
Miscellaneous	†1.005	.348	.632	.139	.011	.163	1.096
Total metered to consumers	33.715	28.485	26.562	35.670	18.679	30.633	15.682
Total supplied through Venturi meters	153	89	44	89	83	97	94

* Year 1909, used on account of conditions following great fire in April, 1908.

† For further details see tabulations on pages 107–115 and 123–131.

30.

District during the Year 1908. (Gallons per Capita.)
Mr. Dexter Brackett.)

Melrose.	Revere.	Water-town.	Arling-ton.	Winthrop.	Milton.	Stone-ham.	Swamp-scott.	Lexing-ton.	Bel-mont.	Nahant
15 210	16 240	12 300	10 650	9 030	7 610	6 820	5 830	4 780	5 120	1 090
30.85	5.57	100.00	43.29	3.38	100.00	2.25	68.25	10.96	100.00	21.95
27.84	5.78	91.86	41.35	5.40	78.84	...	49.25	7.80	85.98	37.06
.042	.121	...	.047	...	.113	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
...	...	.020	...	...	.029	...	...	...	.063	...
...	.039	...	...	...	...	...	...	...	...	...
...	...	.119	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
.024	.010	...	...	.285	.041	...	1.514	...	...	...
.269	.058	5.224	.435	...	.355	3.548	...	...	...	...
.089	.097	1.958	7.674	.266	1.102	.231	1.157	1.001	11.767	...
...	.721	.123	.584	...	...	...	...	.034	...	...
.168	.035	.024	.077	.312	.057	...	.696	...	.223	.761
...	...	...	...	...	...	...	...	...	...	...
.308	.357	.099	...	.047	.187	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	.020	...
.494	.064	.835	.606	.111	.488	...	.071	...	.641	...
.007	...	...	.455	...	...	.105	...	...	...	...
.221	.341	.213	.413	.086	.063	1.965	...	1.040	.053	...
...	...	.024	...	...	...	...	...	...	...	...
.011	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	5.954
...	...	.049	...	...	...	...	...	...	...	...
.444	.048	.236	.267	...	.635	.239	.443	...	.245	2.371
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
2.077	1.891	8.924	10.558	1.107	3.070	6.088	3.881	2.075	13.012	9.086
8.413	2.112	15.355	13.653	1.907	21.248	...	17.165	3.000	17.631	25.424
...	.476	10.537	1.881	2.897	5.784	...	1.310	...	2.696	2.841
.996	1.085	.510	.304	.070	.506	...	.060	.462	6.003	3.002
11.486	5.564	35.326	26.396	5.981	30.608	6.088	22.416	5.537	39.342	40.353
89	78	60	91	103	44	92	76	77	71	70

TABLE 31.

Water Supplied through Meters for Manufacturing, Mechanical, and Trade Purposes, during the Year 1902.

(From " Consumption and Waste of Water," by D. Brackett, Journal N. E. W. W. A., Vol. 18, p. 120, 1904.)

(Gallons per Capita per Day.)

	Boston.	Somerville.	Chelsea.	Malden.	Everett.	Quincy.	Medford.	Melrose.	Revere.	Watertown.	Arlington.	Milton.	Winthrop.	Stoneham.	Belmont.	Lexington.	Nahant.	Swampscott.	Metropolitan District.
Bakeries	.07	.06	.18	....	.04	....	....	.03	....	....	....	....	....	....	....	....	....	....	.06
Breweries and bottling	.96	.10	....	....	.04	....	....	....	....	....	....	....	....	....	....	....	....	....	.65
Electric companies	1.73	.62	....	1.40	....	.31	....	....	1.42	....	....	....	....	....	....	.58	....	....	1.29
Elevators and motors	1.70	.09	.04	.08	.02	....	.08	.07	.01	....	....	.04	.03	....	.03	....	....	....	1.16
Factories and machine shops	2.10	.73	6.15	.85	.37	2.03	.48	.19	....	1.91	.09	.11	....	1.74	....	....	....	....	1.86
Farms and greenhouses	.04	.02	....	.04	....	.02	.02	.16	.10	1.06	4.12	.01	....	.23	4.76	....	....	....	.12
Gas works	.31	....	.05	.11	13.46	....	....	....	....	....	.23	....	....	....	....	.28	....	....	.63
Hotels	2.70	.07	.13	.08	....	.06	.08	.16	.16	....	.18	....	....	....	....	....	....	....	1.83
Iron works	.29	.01	.35	....	1.22	....	....	....	....	....	....	....	....	....	....	....	....	....	.25
Laundries	.41	....	.12	.01	.05	....	.29	.08	....	....	....	.02	....	....	....	....	....	....	.29
Offices and stores	5.12	.39	.12	.70	.23	.28	.63	.19	....	.64	.41	.07	....	....	.03	....	....	....	3.53
Oil and chemicals	.12	.16	.06	.06	2.61	....	.68	.04	....	....	.02	....	....	....	....	....	....	....	.19
Railways	5.62	5.63	2.62	.04	.04	....	1.03	.17	....	.66	.67	.01	....	1.17	.19	1.67	....	....	4.35
Restaurants and saloons	.85	....	....	....	.11	....	....	....	....	....	....	....	....	....	....	....	.10	....	.57
Shipping	.77	.10	1.25	.06	....	.10	....	....	....	....	....	....	....	....	....	....	.27	....	.57
Slaughtering	.09	5.35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.46
Stables	.59	.48	1.27	.15	.19	.01	.15	.45	....	....	....	.36	....	.18	.05	....	1.21	....	.51
Sugar refineries	1.12	....	....	....	....	2.32	....	....	....	....	....	....	....	....	....	....	....	....	.82
Miscellaneous	.30	.11	.01	.35	.22	1.58	.45	....	.19	....	.38	4.07	.14	....	....	....	....	....	.33
Totals	24.90	13.98	12.38	3.93	18.61	6.72	3.89	1.54	1.88	4.27	6.11	4.69	.17	3.34	5.06	2.52	1.58	....	19.47

TABLE 32.

Water Supplied by Meter (only) for Manufacturing, Mechanical and Trade Uses, in the Metropolitan Water District.

(By courtesy of Mr. Dexter Brackett.)

Boston, 1908.

(Population, 643 810.)

Manufacturing, Mechanical, and Trade.

		Number.	Gallons.	Per Capita per Day.
Bakeries		24	18 517 100	.079
Breweries and bottling		62		
Massachusetts Breweries Co.	44 805 200			
Others	161 351 000			
			206 156 200	.875
Cold storage plants		3	55 194 900	.234
Contractors		2	2 685 300	.011
Creameries		1	3 986 800	.017
Dye works		7	5 565 400	.024
Electric companies (Edison Elec. Ill. Co.)		1	190 687 600	.809
Elevators and motors		340	138 178 100	.586
Engines and boilers		8	3 111 700	.013
Factories and machine shops		285	428 716 200	1.820
Farms and greenhouses		11	8 617 000	.037
Fish packing houses		33	19 253 500	.082
Gas works (Boston Consolidated Gas Co.)		1	114 900 300	.488
Hotels		166		
Touraine	46 076 800			
Parker House	37 549 600			
United States	36 210 700			
Adams House	32 687 600			
Others	568 195 800			
			720 720 500	3.059
Iron works		34	49 779 400	.211
Laundries		71	154 505 900	.656
Milk depots		2	22 679 400	.096
Offices and stores			1 585 399 500	6.728
Oils and chemicals		8	9 731 500	.041

		Number.	Gallons.	Per Capita per Day.
Railways:				
Boston & Maine	459 997 600			
Boston Elevated	614 609 200			
Boston, Revere Beach & Lynn	45 740 200			
Boston Terminal Co.	125 866 000			
N. Y. Central & Hudson River,	261 904 700			
N. Y., N. H. & H.	477 919 600			
Old Colony St. Ry.	381 500			
Union Freight R. R.	2 012 100			
			1 988 430 900	8.439
Restaurants		48	42 395 400	.180
Rubber works		4	12 306 900	.052
Saloons		104	46 733 600	.198
Shipping, wharves, etc.		64	216 343 600	.918
Slaughtering		2	24 968 200	.106
Stables		339	169 242 500	.718
Stone crushers		7	1 488 500	.006
Stone works		6	19 605 100	.083
Storage warehouses		27	26 157 600	.111
Sugar refineries		1	246 196 700	1.045
Tanneries		5	3 366 000	.014
			6 535 621 300	27.736

Somerville.

(Population, 74 400.)

		Number.	Gallons.	Per Capita per Day.
Bakeries		7	913 300	.033
Breweries		1	2 137 800	.078
Coal dealers		1	668 700	.025
Contractors		2	801 900	.029
Dye works		2	4 730 400	.174
Electric companies		1	374 700	.014
Elevators and motors		8	1 765 300	.065
Factories and machine shops		43	37 133 000	1.364
Farms and greenhouses		2	750 200	.028
Hotels		10	4 731 800	.174
Iron works		1	112 700	.004
Laundries		5	12 431 000	.456
Offices and stores		535	19 669 100	.722
Oils and chemicals		1	712 100	.026
Railways		2		
Boston & Maine	148 789 900			
Boston Elevated	2 964 300			
			151 754 200	5.573

		Number.	Gallons.	Per Capita per Day.
Slaughtering		3		
North Packing & Provision Co.,	92 847 700			
John P. Squire	59 820 600			
N. E. Dressed Meat & Wool Co.,	43 627 800			
			196 296 100	7.209
Stables		57	17 805 200	.654
			452 787 500	16.628

Malden.

(Population, 42 140.)

	Number.	Gallons.	Per Capita per Day.
Bakeries	3	229 600	.015
Coal dealers	11	1 302 300	.084
Contractors	2	449 600	.029
Dye houses	1	768 200	.050
Electric companies	1	19 149 500	1.242
Elevators and motors	2	1 828 300	.119
Factories and machine shops	34	16 491 200	1.069
Farms and greenhouses	15	1 371 900	.089
Gas works	2	14 731 100	.955
Hotels	3	806 300	.052
Laundries	6	6 093 200	.395
Offices and stores	278	25 882 600	1.678
Oils and chemicals	2	3 600 900	.234
Railways	3	2 460 200	.160
Rubber works	2	3 197 700	.207
Shipping	1	44 100	.003
Stables	22	2 330 800	.151
Stone works	3	66 600	.004
Tanneries	1	334 400	.022
		101 138 500	6.558

Chelsea.

(Population, 32 190.)

		Number.	Gallons.	Per Capita per Day.
Bakeries		14	2 639 800	.225
Coal dealers		3	2 820 000	.240
Dye works		1	770 400	.066
Electric companies		1	748 000	.064
Elevators and motors		2	104 700	.009
Factories and machine shops		51		
Forbes Lithograph	18 423 200			
Others	38 118 100			
			56 541 300	4.812

		Number.	Gallons.	Per Capita per Day.
Gas works		1	134 600	.011
Hotels		7	1 226 700	.104
Iron works		2	9 447 200	.804
Laundries		6	11 451 900	.975
Offices and stores		356	10 839 400	.922
Oils and chemicals		2	336 600	.029
Railways		3		
Boston & Northern	38 851 100			
Others	2 027 100			
			40 878 200	3.479
Restaurants and saloons		32	3 488 000	.297
Rubber works		2		
Revere Rubber Works	91 218 600			
Boston Rubber Works	59 800			
			91 278 400	7.769
Shipping (1 yard, 3 wharves)			7 495 000	.638
Stables		31	4 645 100	.395
			244 845 300	20.839

Everett.

(Population, 31 930.)

Breweries		4	999 300	.086
Contractors		1	1 032 700	.088
Dye works		1	213 200	.018
Elevators and motors		3	126 400	.011
Factories and machine shops		21		
Massachusetts Steel Casting Co.,	11 781 000			
Others	14 856 000			
			26 637 000	2.279
Farms and greenhouses		7	807 000	.069
Gas works		2		
Boston Consolidated	9 666 400			
New England Gas & Coke Co.	123 982 500			
			133 648 900	11.436
Hotels		1	733 000	.063
Laundries		3	5 460 600	.467
Offices and stores		40	2 618 000	.224
Oils and chemicals		1	36 539 800	3.127
Railways		1	710 600	.061
Stables		4	1 653 100	.141
			211 169 600	18.070

Quincy.

(Population, 31 010.)

	Number.	Gallons.	Per Capita per Day.
Electric companies	1	8 443 700	.744
Elevators and motors	2	115 200	.010
* Factories and machine shops	12	129 363 100	11.398
Farms and greenhouses	10	3 124 400	.275
Gas works	1	1 354 000	.119
† Granite and stone works	53	24 751 300	2.181
Hotels	3	1 665 100	.147
Laundries	5	3 772 900	.333
Offices and stores	45	10 843 600	.955
‡ Railways	3	30 943 300	2.726
Shipping	5	596 600	.053
Stables	11	1 307 200	.115
Miscellaneous	6	743 100	.066
		217 023 500	19.122

Medford.

(Population, 21 920.)

	Number.	Gallons.	Per Capita per Day.
Brick yards	2	2 375 500	.296
Dye works	2	5 034 500	.627
Factories and machine shops	8	3 192 800	.398
Farms and greenhouses	7	845 000	.105
Hotels	1	640 400	.080
Iron works	1	955 800	.119
Laundries	2	1 155 100	.144
Offices and stores	131	3 847 900	.480
Oils and chemicals	2	19 720 400	2.458
Railways	2	12 723 300	1.586
Stables	13	2 107 100	.263
		52 597 800	6.556

* Fore River Ship Building Company used 101 690 600 gal.
† The three largest works used over 3 000 000 gal.
‡ Old Colony St. Ry. Power House used 30 209 000 gal.

Melrose.

(Population, 15 210.)

	Number.	Gallons.	Per Capita per Day.
Bakeries	2	235 400	.042
Elevators and motors	3	131 200	.024
Factories and machine shops	4	1 495 700	.269
Farms and greenhouses	5	494 500	.089
Hotels	3	933 400	.168
Laundries	2	1 713 200	.308
Offices and stores	99	2 750 400	.494
Oils and chemicals	1	41 000	.007
Railways	2	1 229 100	.221
Rubber works	1	64 200	.011
Stables	15	2 473 000	.444
		11 561 100	2.077

Revere.

(Population, 16 240.)

Bakeries	1	717 700	.121
Contractors	2	231 900	.039
Elevators and motors	2	58 800	.010
Farms and greenhouses	2	579 700	.097
Gas and electric companies	1	4 288 900	.721
Hotels	1	209 100	.035
Laundries	1	2 119 600	.357
Manufacturing establishments	2	342 200	.058
Offices and stores	3	378 500	.064
Railways	2	2 026 000	.341
Stables		287 900	.048
		11 240 300	1.891

Watertown.

(Population, 12 300.)

	Number.	Gallons.	Per Capita Per Day.
Coal yard	1	89 800	.020
Dye houses	1	533 300	.119
Factories and machine shops	15	23 518 600	5.224
Farms and greenhouses	31	8 813 600	1.958
Gas works	1	552 000	.123
Hotels	1	108 500	.024
Laundries	4	446 600	.099
Offices and stores	60	3 759 200	.835
Railways	2	960 400	.213
Restaurants	3	110 000	.024
Slaughtering	1	221 400	.049
Stables	15	1 062 200	.236
		40 175 600	8.924

Arlington.

(Population, 10 650.)

Bakeries	1	184 400	.047
Factories and machine shops	4	1 697 400	.435
Farms and greenhouses	50	29 911 800	7.674
Gas works	1	2 276 200	.584
Hotels	2	299 100	.077
Offices and stores	45	2 361 800	.606
Oils and chemicals	1	1 773 400	.455
Railways	3	1 608 400	.413
Stables	9	1 041 900	.267
		41 154 400	10.558

Winthrop.

(Population, 9 030.)

Elevators and motors	2	941 800	.285
Greenhouses	1	878 500	.266
Hotels	1	1 031 300	.312
Laundries	1	154 400	.047
Offices, stores, etc.	10	367 700	.111
Railways	1	286 300	.086
		3 660 000	1.107

Milton.

(Population, 7 610.)

	Number.	Gallons.	Per Capita Per Day
Bakeries	2	314 500	.113
Coal wharf	1	81 500	.029
Elevators and motors	2	114 400	.041
Factories and machine shops	5	989 900	.355
Farms and greenhouses	30	3 070 400	1.102
Hotels	1	157 500	.057
Laundries	2	520 200	.187
Offices and stores	16	1 358 300	.488
Railways	3	175 000	.063
Stables	34	1 770 100	.635
		8 551 800	3.070

Stoneham.

(Population, 6 820.)

Factories and machine shops	9	8 856 500	3.548
Farms and greenhouses	5	576 300	.231
Oils and chemicals	1	263 100	.105
Railways	1	4 904 200	1.965
Stables	2	595 600	.239
		15 195 700	6.088

Swampscott.

(Population, 5 830.)

Elevators and motors	2	3 229 100	1.514
Farms and greenhouses	3	2 469 000	1.157
Hotels	1	1 485 400	.696
Offices and stores	9	152 100	.071
Stables	9	945 300	.443
		8 280 900	3.881

Lexington.

(Population, 4 780.)

	Number.	Gallons.	Per Capita Per Day.
Farms and greenhouses	9	1 751 200	1.001
Gas works	1	60 500	.034
Railways	2	1 818 900	1.040
		3 630 600	2.075

Belmont.

(Population, 5 120.)

Blacksmith and carriage shop	1	38 100	.020
Coal company	1	118 600	.063
Farms and greenhouses	88	22 050 300	11.767
Hotels	1	417 400	.223
Offices and stores	23	1 201 300	.641
Railways	1	99 500	.053
Stables	7	457 900	.245
		24 383 100	13.012

Nahant.

(Population, 1 090.)

Hotels	1	303 600	.761
Shipping		2 375 400	5.954
Stables	4	945 700	2.371
		3 624 700	9.086

The consumption of water for trade purposes in Fall River during the year 1910, amounted to 281 886 267 gal., or 6.5 gal. per capita.

Mr. James H. Fuertes, in his report to the Merchants' Association of New York, 1906, gives the following subdivision of water consumption, as between domestic, manufacturing, and public uses:

TABLE 33.

SUBDIVISION OF CONSUMPTION INTO VARIOUS USES.

(Report of Mr. Jas. H. Fuertes to Merchants' Association, New York, 1906.)

(In Gallons per Day per Capita.)

Place.	Year.	Consumers' Use.			Public Uses.	Not Accounted For.	Total Cons.	Per Cent. Unaccounted For.	Per Cent. Metered
		Mfg.	Domestic.	Total.					
Brockton .	1904	5.1	15.5	20.6	3.0	13.3	36.9	26	91
Boston . . .	1892	30.0	30.0	60.0	3.0	32.0	95.0	34	. .
Cleveland.	1904	40.0	26.0	66.0	10.0	20.0	96.0	21	49
Fall River	1902	. . . .	. . . .	23.4	8.3	8.7	40.5	21	95
Hartford. .	1904	3.0	30.0	33.0	5.0	24.0	62.0	39	99
Harrisburg	1904	81.0	30.0	111.0	5.0	30.0	146.0	21	75±
Lawrence .	1904	8.0	17.0	25.0	5.0	12.0	42.0	29	87
Milwaukee	1904	45.0	25.0	70.0	5.0	14.0	89.0	16	79
Madison. .	1904	. . . .	. . . .	21.0	13.0	37.0	71.0	52	96
Syracuse. .	1904	39.3	31.0	70.3	18.0	20.0	108.3	19	72
Taunton. .	1904	14.7	21.5	36.2	3.0	24.8	64.0	39	45
Wellesley .	1904	0.4	28.6	29.0	2.5	23.5	55.0	43	100
Yonkers . .	1904	24.0	20.0	57.5	2.0	40.5	94.0	43	100

Mr. Rudolph Hering reports the following use of water for trade purposes in Germany:

TABLE 34.

WATER CONSUMPTION IN GERMANY FOR DIFFERENT PURPOSES, 1909.

(From report of Mr. Rudolph Hering to Mr. J. Waldo Smith, Chief Engineer, New York Additional Water Supply, by courtesy of the latter.)

For Trade Purposes (daily).

	Liters. Per Day.	U. S. Gal. Per Day.
Feed water for condensing engines, per h.p. per hour . .	6–12	1.58–3.17
Feed water for small non-condensing engines, per h.p. per hour	25–35	6.60–8.24

Water for condensation is 25 to 35 times the feed water.

For breweries, five times the quantity of produced beer.

For cleaning one carriage, 200 liters (52.84 U. S. gal.).

For horses and cattle, per head, 30 to 50 liters (7.92 to 13.2 U. S. gal.).

Public Uses.

AT FIRES.

The total amount of water used at fires during the course of the year is comparatively small. The rate at which the water is used for short periods of time at different fires, is, on the other hand, likely to be large. In the following table are shown some of the standards of service suggested in the past by different engineers and underwriters. These are followed by diagrams reprinted from a paper presented by Metcalf, Kuichling, and Hawley, before the American Water Works Association, June, 1911.

TABLE 35.

Standards for Amount of Water required for Fire Protection.

J. Herbert Shedd, Journal N. E. W. W. A., Vol. 3, p. 113, March, 1889, suggests for population of —

5 000	5 streams of 200 gal.
10 000	7 streams of 200 gal.
20 000	10 streams of 200 gal.
40 000	14 streams of 200 gal.
60 000	17 streams of 200 gal.
100 000	22 streams of 200 gal.
180 000	30 streams of 200 gal.

John R. Freeman, Journal N. E. W. W. A., Vol. 7, p. 49, September, 1892:

Total Population.	No. of 250-gal. Streams required simultaneously in Addition to Maximum Domestic Draft.
1 000	2 to 3
5 000	4 to 8
10 000	6 to 12
20 000	8 to 15
40 000	12 to 18
60 000	15 to 22
100 000	20 to 30
200 000	30 to 50

Ten of the streams to be concentrated for any large group of buildings, irrespective of small population, if possible. In a city, two thirds of the streams mentioned should be capable of being concentrated on a large square.

Kuichling-Hazen, 1897:

$$C=Q+20P+1\,000\,000\sqrt{\frac{P}{1\,000}}.$$

C = Required capacity of plant in g.p.d.
Q = Average daily quantity consumption, in gallons.
P = Population.

TABLE 35 (*Continued*).

STANDARDS FOR AMOUNT OF WATER REQUIRED FOR FIRE PROTECTION.

UNDERWRITERS ASSOCIATION OF THE MIDDLE DEPARTMENT, July, 1904:

Fire streams, 250 g.p.m. Domestic, 50 to 80 g.p.d. per capita.

Population.	Streams.	Fire Flow	Domestic.	Total (Mgd.).
1 000	2	0.72	0.05	0.77
2 000	3	1.08	0.10	1.18
3 000	5	1.80	0.15	1.95
4 000	7	2.52	0.20	2.72
5 000	8	2.88	0.25	3.13
6 000	8	2.88	0.30	3.18
8 000	9	3.24	0.45	3.69
10 000	9	3.24	0.60	3.84
15 000	10	3.60	1.00	4.60
20 000	11	3.96	1.40	5.36
25 000	12	4.32	1.90	6.20
30 000	12	4.32	2.40	6.72

J. T. FANNING, AM. W. W. A., 1906:

4 000 to 10 000	7 to 19 fire streams 54 lb. at nozzle.
10 000 to 50 000	10 to 14 fire streams 54 lb. at nozzle.
50 000 to 100 000	14 to 18 fire streams 54 lb. at nozzle.
100 000 to 150 000	18 to 25 fire streams 54 lb. at nozzle.

$1\frac{1}{8}$ in. nozzle (smooth), 250 ft. rubber-lined hose, 43 lb. base of nozzle, 68 ft. effective height, 247 gal. per minute.

THE NATIONAL BOARD OF FIRE UNDERWRITERS (courtesy of Geo. W. Booth, March, 1911), have prepared a plot of the engine capacity in gallons per minute in all of the cities examined, giving not only the actual rated capacity, but the total capacity including recommendations of the board. These cities indicated that Mr. Kuichling's summary is adequate for populations up to 1 000; fairly represents the actual conditions in cities of 200 000 or 250 000 population; but gives altogether too small results for the large cities. The underwriters' investigations indicate that a straight line, rather than a curve, more nearly meets actual conditions and their requirements. They indicate requirements corresponding to the following summary.

Required engine capacity allowance, 2 000 g.p.m. + 58 × population in thousands.

A more conservative line, which seems to me preferable, which they also show, is as follows:

Required engine capacity = 1 000 g.p.m. + 58 × population in thousands.

TABLE 35 (*Continued*).

STANDARDS FOR AMOUNT OF WATER REQUIRED FOR FIRE PROTECTION.

MR. GEORGE W. BOOTH, CHIEF ENGINEER OF THE NATIONAL BOARD OF FIRE UNDERWRITERS, presents the following data in regard to their present standards, under date March 22, 1911:

Required engine capacity = 2 000 g.p.m. + 58 × population in thousands.

Required engine capacity = 1 000 g.p.m. + 58 × population in thousands.

Number of engine companies = 4 + 0.8 × population in thousands.

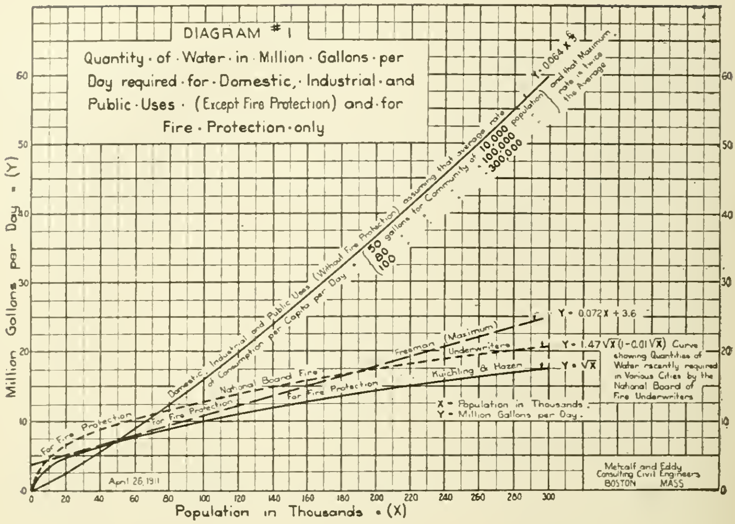


DIAGRAM # 1
Quantity · of · Water · in · Million · Gallons · per Day required · for · Domestic, · Industrial · and Public · Uses · (Except Fire Protection) and · for Fire · Protection · only
Million Gallons per Day - (Y)
Population in Thousands - (X)
Y = 0.072X + 3.6
Y = 1.47√X(1 - 0.01√X) Curve showing Quantities of Water recently required in Various Cities by the National Board of Fire Underwriters
Y = √X
X = Population in Thousands
Y = Million Gallons per Day
Freeman (Maximum)
Underwriters
Kuichling & Hazen
National Board Fire
For Fire Protection
Metcalf and Eddy Consulting Civil Engineers BOSTON MASS
April 26, 1911

Fig. 16.

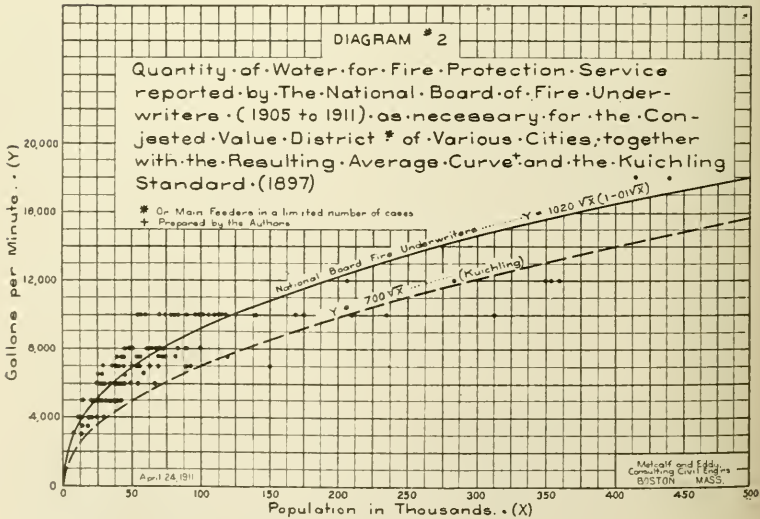


DIAGRAM # 2
Quantity · of · Water · for · Fire · Protection · Service reported · by · The · National · Board · of · Fire · Underwriters · (1905 to 1911) · as · necessary · for · the · Congested · Value · District * of · Various · Cities, · together with · the · Resulting · Average · Curve+ · and · the · Kuichling Standard · (1897)
* Or Main Feeders in a limited number of cases
+ Prepared by the Authors
National Board Fire Underwriters
Y = 1020 √X (1 - .01√X)
Y = 700 √X (Kuichling)
Gallons per Minute - (Y)
Population in Thousands - (X)
Metcalf and Eddy Consulting Civil Engineers BOSTON MASS.
April 24, 1911

Fig. 17.

THE USE OF WATER IN SCHOOLS.

Tables 36 and 37 cover the use of water in schools in the Metropolitan District, surrounding Boston, and in Syracuse, N. Y.

TABLE 36.

WATER USED FOR SCHOOLS AND STREETS IN METROPOLITAN DISTRICT.
(M. & E., in reports of Boston Finance Commission, Vol. 3, October, 1908.)

City or Town.	Schools.			Street Sprinkling, 1901.
	Year.	Daily Consumption.		Metropolitan District. Gal. per Capita per Day.
		Per Pupil.	Per Inhabitant.	
Arlington	1901	....	....	2.12
Belmont	1902	6.96	0.48	1.47
Boston	1899	6.22	0.41	2.35
Chelsea	....	....	....	1.12
Malden	1901	2.21	0.17	1.87
	1902	2.26	0.18	....
Medford	1901	4.02	0.33	3.41
	1902	4.11	0.34	....
Melrose	....	....	....	2.06
Milton	1901	6.56	0.53	5.87
Nahant	....	....	....	8.63
Quincy	....	....	....	1.43
Revere	....	....	....	0.96
Somerville	1899	6.29	0.46	1.97
Stoneham	....	....	....	0.60
Swampscott	....	....	....	3.67
Watertown	....	....	....	3.67
Winthrop	....	....	....	2.48

Average for Metropolitan Water District 2.13

John Venner, "Municipal Use and Waste of Water," in JOURNAL N. E. W. W. A., Vol. 17, p. 268, September, 1903, gives data on use of water in the 34 public schools of Syracuse, N. Y., three months, March–May, 1903.

The following table shows the daily consumption of water per pupil, in gallons, based upon the average daily attendance in each school.

TABLE 37.

DAILY CONSUMPTION OF WATER PER PUPIL IN THE PUBLIC SCHOOLS OF SYRACUSE, N. Y., FOR THREE MONTHS OF 1903.

School.	Average Daily Attendance.	Per Capita Consumption, in Gallons.		
		March.	April.	May.
1. Jefferson	314	17.8	21.1	24.1
2. Grant	304	22.2	25.2	24.4
3. Townsend	481	5.4	5.7	5.5
4. Garfield	434	5.1	6.6	5.2
5. Franklin	826	4.1	3.5	2.4
6. Prescott	574	9.4	9.2	6.0
7. Clinton	522	16.2	15.3	14.7
8. Lincoln	414	9.1	8.0	7.8
9. Vine	218	2.3	4.2	4.1
10. Frazer	428	12.8	14.2	11.0
11. Genesee	412	6.0	3.2	2.9
12. Commercial	86	397.0	381.0	497.0
13. May	426	110.0	114.0	117.0
14. Tompkins	388	5.6	6.1	8.7
15. Porter	778	4.5	4.5	3.2
16. Gere	352	33.0	33.5	22.5
17. Madison	529	40.7	39.4	32.8
18. Sumner	358	20.9	20.0	15.7
19. Washington Irving	439	35.3	30.9	22.6
20. Willard	81	188.8	190.0	104.4
21. Montgomery	471	5.1	4.1	4.0
22. Putnam	650	21.6	16.7	12.6
23. Andrew Jackson	353	3.5	2.9	3.9
24. Croton	605	44.5	31.2	28.0
25. New High School	1 267	8.9	9.4	9.0
26. Seymour	665	26.3	23.6	23.6
27. Truant School	16	22.3	38.2	52.2
28. Delaware	523	7.5	9.2	6.6
29. Grace	259	16.8	24.3	30.9
30. Merrick	294	35.6	17.9	22.3
31. Bellevue	257	32.1	32.8	37.9
32. Danforth	348	25.9	21.4	22.0
33. Elmwood	224	8.4	14.5	14.5
34. Brighton	868	5.3	4.1	3.0

Average, 20 gal.

For the three months, the use in the schools amounted to 3.6 per cent. of the entire consumption of the city.

The general uses of water for public purposes are indicated by the statistics shown in Tables 38 to 44, covering the public uses of water in the cities and towns of the Metropolitan District, Brookline, Fall River, Woonsocket, Canandaigua, and Cleveland.

TABLE 38.

WATER SUPPLIED BY METER (ONLY) FOR PUBLIC PURPOSES IN THE METROPOLITAN WATER DISTRICT. 1908.

(By courtesy of Mr. Dexter Brackett.)

Boston.

(Population, 643 810.)

		Number.	Gallons.	Per Capita per Day.
Boston Protective Department Wagon No. 2			471 000	.002
Cemeteries		2	3 186 500	.013
Colleges		10	51 784 000	.220
Metropolitan Water and Sewerage Board			39 733 800	.169
National, state, or county buildings		15		
Navy Yard	211 953 300			
U. S. Gov., Gallups Is.	25 783 600			
Post Office	23 621 800			
State Prison	19 799 600			
State House	15 805 200			
Others	34 677 300			
			331 640 800	1.407
Schools:				
Private		14	8 355 200	.072
Parochial		21	8 512 200	
State Board of Health, Pathological Laboratory,			351 600	.010
Street watering, Park Department		...	39 045 600	.166
			483 080 900	2.050

(Public schools, public buildings owned by city, street watering, and other public uses are not metered.)

Somerville.

(Population, 74 400.)

	Number.	Gallons.	Per Capita per Day.
Metropolitan Park Commission, Wellington Bridge		162 300	
Metropolitan Sewerage Works, Alewife Brook Pumping Station		1 085 300	
National, state, or county buildings (armory)	1	543 000	
St. Joseph's Parochial School		225 200	
Street watering (estimated by street commissioner)		63 912 000	
Tufts College, Metcalf Hall		477 200	
		66 405 000	2.439

(Schools and municipal buildings not metered.)

Malden.

(Population, 42 140.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	2	365 300	
Fire stations	6	653 800	
High school field		20 000	
Metropolitan Park boulevard		88 100	
Municipal departments		1 142 900	
National, state, or county buildings		1 161 600	
Schools:			
Public	20	7 004 000	
Private	1	53 900	
Parochial	2	214 700	
Street watering (figured by cartloads)		42 468 300	
		53 172 600	3.448

Chelsea.

(Population, 32 190.)

		Number.	Gallons.	Per Capita per Day.
Drawtender's house, Chelsea Bridge			546 000	
National, state, or county buildings:				
Court house	1 735 400			
Naval hospital	10 756 200			
Soldiers' home	14 960 000			
			27 451 600	
Schools:				
Public		4	3 545 500	
Parochial		1	306 700	
Street watering (record kept by cartloads)			7 870 800	
			39 720 600	3.381

Everett.

(Population, 31 930.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	2	1 026 300	
Municipal departments	1	471 200	
Public fountains	1	21 700	
Schools, public	1	590 900	
State armory	1	102 500	
		2 212 600	.189

Quincy.

(Population, 31 010.)

	Number.	Gallons.	Per Capita per Day.
Metropolitan Sewerage Works		3 097 800	
Metropolitan Park Commission		970 400	
Street watering (estimated by commissioner)		23 560 000	
United States Government (Fort Andrew)		22 553 000	
		50 181 200	4.421

Medford.

(Population, 21 920.)

	Number.	Gallons.	Per Capita per Day.
Fire stations	5	393 900	
Metropolitan Park Commission		340 000	
Metropolitan Water Works, Glenwood Pipe Yard		130 000	
Municipal departments		1 334 200	
National, state, or county buildings	1	519 400	
Public schools	18	3 995 300	
Street watering (estimated from data furnished by water registrar)		24 562 700	
		31 275 500	3.898

Melrose.

None.

Revere.

(Population, 16 240.)

	Number.	Gallons.	Per Capita per Day.
Metropolitan Park (public fountain)		76 500	
Municipal departments		402 700	
Schools, public	9	2 349 000	
		2 828 200	.476

Watertown.

(Population, 12 300.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	2	493 700	
Fire station		216 900	
Municipal departments		1 178 900	
Schools:			
Public	10	2 930 700	
Private	1	70 300	
Parochial		10 500	
Street watering		19 618 900	
Watertown arsenal		22 915 700	
		47 435 600	10.537

Arlington.

(Population, 10 650.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	1	15 900	
Public library		316 300	
Street watering (estimated by town engineer)		7 000 000	
		7 332 200	1.881

Winthrop.

(Population, 9 030.)

	Number.	Gallons.	Per Capita per Day.
Schools, public	3	400 600	
Street watering (figured by cartloads)		7 635 000	
United States government buildings		1 539 300	
		9 574 900	2.897

Milton.

(Population, 7 610.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	1	121 300	
Fire stations	3	211 300	
Metropolitan Park Commission, street watering		1 293 700	
Metropolitan Park Commission, fountain, police station, etc.		257 100	
Municipal departments	9	635 300	
Public fountains	4	946 100	
Schools:			
Public	8	1 353 500	
Private	2	2 144 300	
Street watering		9 146 000	
		16 108 600	5.784

Stoneham.

	Number.	Gallons.	Per Capita per Day.
None.			

Swampscott.

(Population, 5 830.)

	Number.	Gallons.	Per Capita per Day.
Municipal departments	2	144 400	
Public schools	4	2 650 600	
		2 795 000	1.310

Lexington.

None.

Belmont.

(Population, 5 120.)

	Number.	Gallons.	Per Capita per Day.
Cemeteries	1	369 500	
Fire stations	1	38 100	
Metropolitan Park		60 600	
Schools:			
Public	5	1 131 000	
Private	1	114 400	
Street watering (estimated by superintendent of streets)		2 640 000	
Town departments		699 400	
		5 053 000	2.696

Nahant.

(Population, 1 090.)

	Number.	Gallons.	Per Capita per Day.
State bath house	1	1 133 400	2.841

TABLE 39.

WATER SUPPLIED BY METER (ONLY) FOR MISCELLANEOUS PURPOSES IN THE METROPOLITAN WATER DISTRICT, 1908.

(By courtesy of Mr. Dexter Brackett.)

Boston (1908).

(Population, 643 810.)

		Number.	Gallons.	Per Capita per Day.
Clubs		36	67 110 600	.285
Halls		10	13 314 400	.057
Homes		11	8 587 000	.036
Hospitals		28		
Massachusetts General	30 413 700			
Massachusetts Homœopathic	15 408 800			
Others	48 679 800			
			94 502 300	.401
Laboratories		2	837 800	.004
Museums		2	1 967 200	.008
Playgrounds		3	3 358 500	.014
Public baths		8	6 636 400	.028
Religious societies		12	9 935 300	.042
Skating rinks		2	2 004 600	.009
Theaters		19	28 528 700	.121
			236 782 800	1.005

Somerville.

(Population, 74 400.)

	Number.	Gallons.	Per Capita per Day.
Clubs	4	411 400	
Religious societies	11	7 413 400	
Somerville hospital		1 647 800	
		9 472 600	.348

Malden.

(Population, 42 140.)

	Number.	Gallons.	Per Capita per Day.
Baths	2	310 000	
Clubs	6	402 400	
Halls	2	259 600	
Hospitals	3	3 237 300	
Religious societies	37	4 191 000	
Theaters	1	1 341 200	
		9 741 500	.632

Chelsea.
(Population, 32 190.)

	Number.	Gallons.	Per Capita per Day.
Baths	4	1 084 600	
Clubs	1	15 000	
Halls	2	209 400	
Religious societies	5	320 500	
		1 629 500	.139

Everett.
(Population, 31 930.)

	Number.	Gallons.	Per Capita per Day.
Clubs	1	92 000	
Building purposes		41 900	
		133 900	.011

Quincy.
(Population, 31 010.)

	Number.	Gallons.	Per Capita per Day.
Clubs	5	1 848 600	.163

Medford.
(Population, 21 920.)

	Number.	Gallons.	Per Capita per Day.
Building purposes		5 632 500	
Clubs	2	80 300	
Combination Park		122 200	
Halls	1	32 500	
Pasture taps	6	202 700	
Religious societies	9	703 400	
Sanitariums	1	257 500	
Steam engines	2	173 800	
Theaters	1	94 900	
Tufts College		1 496 900	
		8 796 700	1.096

Melrose.
(Population, 15 210.)

	Number.	Gallons.	Per Capita per Day.
Clubs	2	70 000	
Hospitals	3	561 700	
New England Sanitarium		3 315 700	
Religious societies	4	1 598 000	
		5 545 400	.996

Revere.
(Population, 16 240.)

	Number.	Gallons.	Per Capita per Day.
Amusement places	4	6 167 400	
Theaters	1	283 900	
		6 451 300	1.085

Watertown.

(Population, 12 300.)

	Number.	Gallons.	Per Capita per Day.
Clubs	2	944 700	
Religious societies	12	1 349 400	
		2 294 100	.510

Arlington.

(Population, 10 650.)

	Number.	Gallons.	Per Capita per Day.
Clubs	2	404 400	
Halls	1	30 800	
Institutions	2	734 800	
Religious societies	1	14 400	
		1 184 400	.304

Winthrop.

(Population, 9 030.)

	Number.	Gallons.	Per Capita per Day.
Churches	1	26 600	
Hospitals	1	205 300	
		231 900	.070

Milton.

(Population, 7 610.)

	Number.	Gallons.	Per Capita per Day.
Clubs	2	76 800	
Fire supply (private)	1	74 800	
Hospital	1	405 000	
Religious societies	7	850 500	
Watering trough (private)		2 600	
		1 409 700	.506

Stoneham.

None.

Swampscott.

(Population, 5 830.)

	Number.	Gallons.	Per Capita per Day.
Hospitals	1	17 400	
Religious societies	2	110 100	
		127 500	.060

Lexington.

(Population, 4 780.)

	Number.	Gallons.	Per Capita per Day.
Lexington Park		808 300	.462

Belmont.

(Population, 5 120.)

	Number.	Gallons.	Per Capita per Day.
Clubs	3	191 500	
Religious societies	5	178 000	
McLean Hospital		10 878 900	
		11 248 400	6.003

Nahant.

(Population, 1 090.)

Clubs	1	424 700	
Lawns	4	772 900	
		1 197 600	3.002

TABLE 40.

Brookline, Mass. Public Uses of Water. Record in 1905, All Services Metered.

Bathhouses	2.02 gal. per day per capita.
Miscellaneous public buildings	0.20 gal. per day per capita.
Fire Department buildings	0.12 gal. per day per capita.
Schools	1.13 gal. per day per capita.
Street Department	0.03 gal. per day per capita.
Water Department	1.11 gal. per day per capita.
Drinking fountains	0.83 gal. per day per capita.
Street watering	6.60 gal. per day per capita.
Flushing sewers, extinguishing fires, puddling trenches, etc.	1.01 gal. per day per capita.
Total public uses	13.05 gal. per day per capita.

Of the metered water, the town used 20.7 per cent. and private consumers 79.3 per cent. But 14 per cent. of the water pumped was unaccounted for by the meters.

TABLE 41.

Fall River, Mass. Quantities of Water used for Public Purposes. 1910.

(Population, 118 645.)

	Quantity in Million Gallons.	Consumption, in Gallons per Capita per Day.
Schools	77 500 000	1.79
Public buildings	54 891 170	1.27
Street watering	131 000 000	3.03
Sewer flushing	18 450 000	0.43
Fires	12 700 000	0.29
Water troughs and urinals	104 800 000	2.42
Miscellaneous	154 300 000	3.56
Total		12.79

TABLE 42.

Cleveland, Ohio. AMOUNT OF WATER FURNISHED FREE FOR PUBLIC PURPOSES, OCTOBER 1, 1909, TO OCTOBER 1, 1910.
From report of Department of Public Works.)

	Total Consumption (Million Gallons).	Gallons per Capita per Day. Figured on Total Population (630 000).
Public schools	266.6	1.16
Private and parochial schools	46.4	0.20
Hospitals	175.3	0.76
Orphan asylums, homes, etc.	117.9	0.51
Public buildings (police and fire stations, etc.)	401.1	1.74
Cemeteries	31.9	0.14
Parks and fountains	119.5	0.52
Flushing sewers	62.0	0.27
Cleaning streets	200.0	0.87
Fires	35.1	0.15
Sewer and paving construction	55.4	0.24
Watering troughs	148.7	0.65
Total		6.31

TABLE 43.

Woonsocket, R. I. MUNICIPAL USE OF WATER, 1911.

	Total Consumption (Million Gallons).	Gallons per Capita per Day Figured on Total Population (44 200).
Flushing dead ends	1.0	0.06
Street watering	18.4	1.14
Sewer flushing	0.7	0.04
Drinking fountains	20.0	1.24
Schools	17.0	1.05
Hospitals	1.4	0.09
Charitable institutions	17.3	1.07
Fire Department	0.6	0.04
Public buildings	12.4	0.77
Fires	1.2	0.07
Total		5.57

TABLE 44.

Canandaigua, N. Y. Public Uses of Water, 1911.

	Consumption in Million Gallons, March 1 1910, to March 1, 1911.	Consumption, Gallons per Capita per Day (Population [illegible]).
Asylums	4.44	1.62
Hospitals	3.93	1.43
Churches	1.01	0.37
Public buildings	5.80	2.12
Schools	1.54	0.56
Parks and fountains	2.62	0.96
Pumping station	1.24	0.45
Street sprinkling	8.00 (estimated)	2.92
Sewer flushing	5.00 (estimated)	1.82
Total		12.25

Dexter Brackett, Journal N. E. W. W. A., Vol. 18, p. 127, gives summary of uses for public purposes in cities of Massachusetts Metropolitan Water District for 1902 and finds the total to be 7.11 gal. per capita of population supplied.

Interesting data concerning water consumption for public purposes in Germany were submitted by Mr. Rudolph Hering (1909) to Mr. J. Waldo Smith, chief engineer of the New York Additional Water Supply, by whose courtesy they are reproduced herewith.

TABLE 45.

WATER CONSUMPTION IN GERMANY, FOR DIFFERENT PURPOSES.

For Public Purposes (daily):

	Liters per Sq. Meter.	U. S. Gal. per Sq. Yd.
Paved streets, sprinkling	1.0	0.22
Macadamized streets	1.5	0.33
Gardens and lawns	1.5	0.33
Markets	5.0	1.10
	Liters.	U. S. Gallons.
Sewer flushing, per head of population	1–8	0.264–2.11
Self-flushing urinals, per hour	50.0	13.21
Abattoirs, per animal	300.0	79.26
Hospitals, per person	120.0	30.50
Soldiers in barracks, per person	40.0	10.56
Hotels, per person	100.0	26.4

LEAKAGE AND WATER-UNACCOUNTED-FOR.

The amount of water lost by leakage from main pipes, valves and fittings, service connections, etc., — or, in other words, from the distribution pipe system, independent of the waste of water from the faucets and fixtures connected therewith, — is unfortunately large. In general, it may be said that if, in a well-metered system, the water-unaccounted-for does not exceed 25 per cent. of the total pumpage, the practice is good. If, on the other hand, as is often the case, the leakage or water-unaccounted-for amounts to 40 per cent. or more of the pumpage, the practice is not good and it is probable that measures taken to reduce the amount of this

leakage will effect a substantial saving in leakage and consequent reduction in expense of operation.

Two of the best discussions in American literature upon the waste and leakage of water are to be found in the paper of Mr. Dexter Brackett, chief engineer of the Metropolitan Water Works, of Boston, upon "Report on the Measurement, Consumption and Waste of Water Supplied to the Metropolitan Water District," published in the JOURNAL of this Association in June, 1904, Volume 18, and in the report upon New York's Additional Water Supply, rendered to the comptroller of the city, by Mr. John R. Freeman, March 23, 1910.

In Mr. Brackett's article will be found diagrams 1 to 7, bearing upon the waste and leakage of water. Mr. Brackett says (p. 134):

"The tests which have been made in the several municipalities of the Metropolitan District tend to show that the leakage from the street mains and services is very large, and that from 10 000 to 15 000 gal. per mile of street main escape each day into the ground or into some underground channel. If this estimate is correct, the total leakage from the mains and services is from 15 000 000 to 22 500 000 gal. per day, — equivalent to from 16.5 to 25 gal. per inhabitant."

Mr. Freeman's discussion, with accompanying diagrams, will be found on pp. 38 to 83, "Report on New York's Water Supply." He says, —

"My best guess is that the total leakage underground in the streets at present amounts to somewhere between 20 and 35 gal. per inhabitant per day.

"It can never be known with any degree of accuracy just what this underground leakage in the street is until there is a meter on every tap and a daily estimate made of all public uses and draft for fires, when by subtracting what is measured out from what is measured into the distribution system, the difference will give the leakage from the street pipes. This kind of measurement in Fall River and Woonsocket, with the allowance for a smaller number of joints and of service pipes in New York, gives us the ideal of 5 to 10 gal. per inhabitant per day, for maximum leakage of street mains and service pipes toward which the water distribution service of Greater New York should work. To attain this ideal will require years of patient work and very heavy expenditure."

In Mr. Brackett's report of 1904, the following similar conditions, in cities having metered water supplies, are shown.

TABLE 46.

WATER-UNACCOUNTED-FOR IN CITIES WITH METERED SUPPLIES.

City.	Per Cent. Metered.	Unaccounted For.	
		Per Cent.	Gallons per Day per Mile of Pipe.
Brockton	90	32.3	6 200
Ware	100	39.8	11 200
Worcester	94.5	46.5	20 800
Wellesley	100	41.5	3 450
Yonkers	100	45.7	23 340
Fall River	96	21.5	10 000
Woonsocket	87	23.0	4 370

Mr. T. C. Phillips, engineer of water surveys of Chicago, in a recent article (*Engineering and Contracting,* January 1, 1913, p. 11) estimates the present "willful wastage and underground leakage" at 30 per cent. of the daily consumption, or 57 gal. daily per capita, and the "plumbing leakage" at 20 per cent., or 38 gal. daily per capita. In answer to the question, what becomes of the water pumped, he gives the following table:

(1) 37.0 gal. per capita is consumption by frontage consumers.
(2) 44.0 gal. per capita is consumption by meter consumers.
(3) 9.5 gal. per capita is consumption by free service consumers.
(4) 4.5 gal. per capita is slippage of or loss by meters.
(5) 38.0 gal. per capita is plumbing leakage.
(6) 57.0 gal. per capita is willful wastage and underground leakage.

190.0 gal. per capita is total consumption for entire city.

The two following diagrams illustrating the conditions at East Chicago and Indiana Harbor, Ind., and at San Antonio. Tex., reported by Metcalf & Eddy, show similar characteristics.

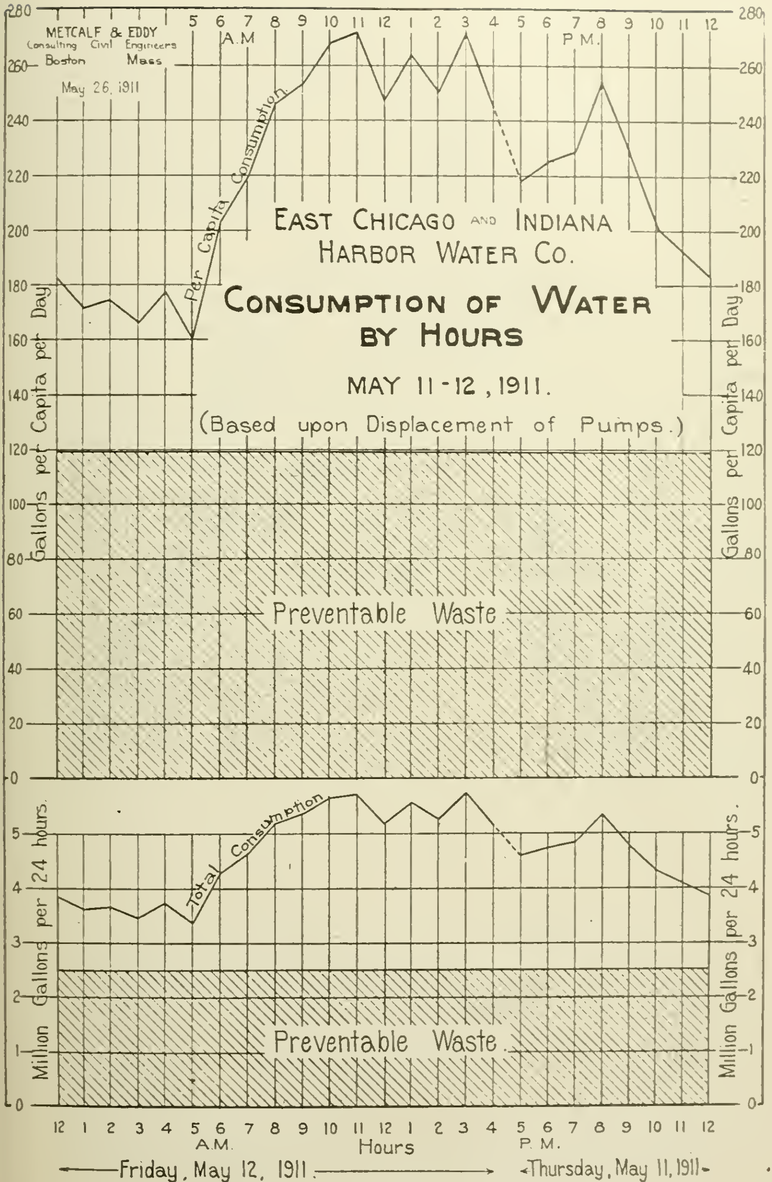
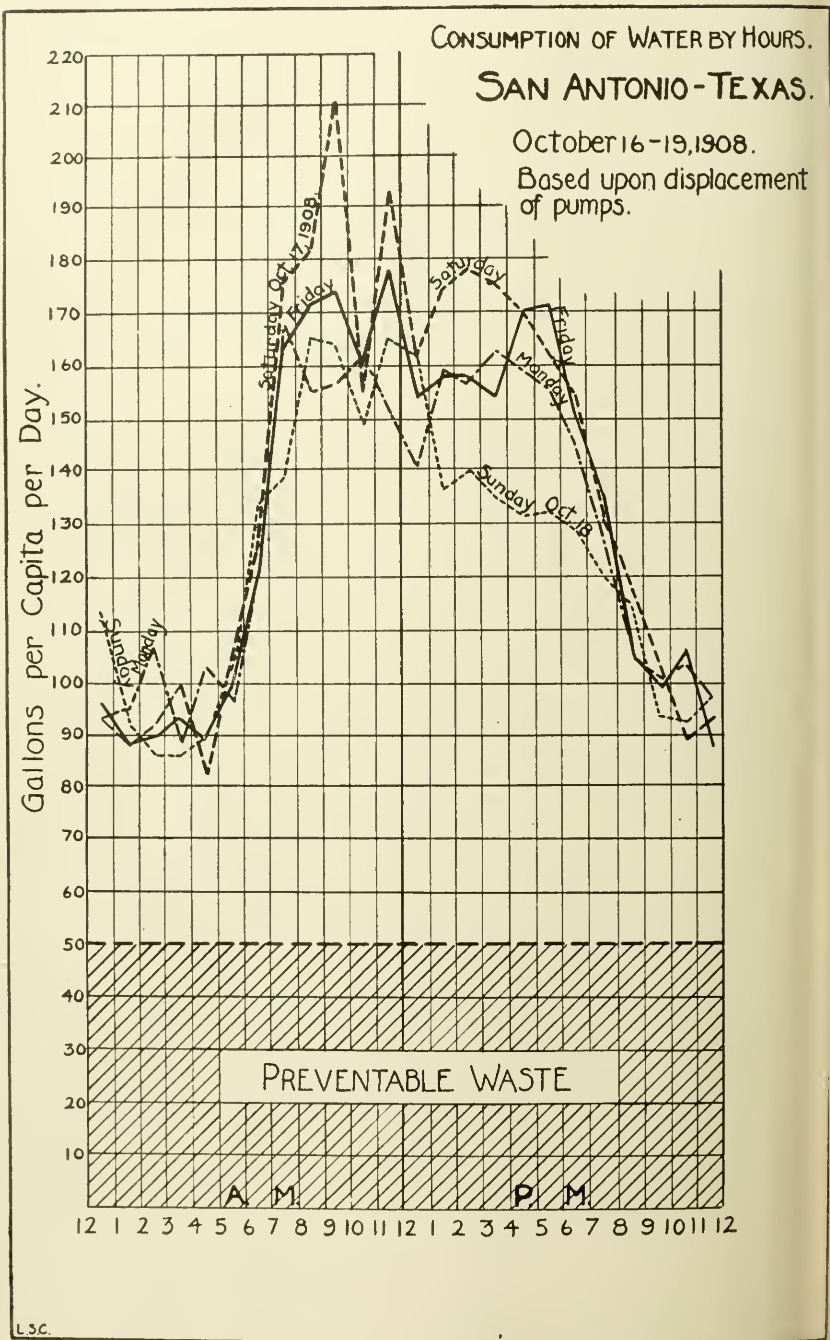

METCALF & EDDY
Consulting Civil Engineers
Boston Mass
May 26, 1911
EAST CHICAGO AND INDIANA
HARBOR WATER CO.
CONSUMPTION OF WATER
BY HOURS
MAY 11-12, 1911.
(Based upon Displacement of Pumps.)
Per Capita Consumption
Preventable Waste
Gallons per Capita per Day
Total Consumption
Preventable Waste
Million Gallons per 24 hours.
A.M.
P.M.
Hours
Friday, May 12, 1911.
Thursday, May 11, 1911

FIG. 18.



CONSUMPTION OF WATER BY HOURS.
SAN ANTONIO-TEXAS.
October 16-19, 1908.
Based upon displacement of pumps.
Gallons per Capita per Day.
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Saturday Oct. 17, 1908.
Friday
Saturday
Monday
Friday
Sunday Oct. 18
Sunday
Monday
PREVENTABLE WASTE
A. M.
P. M.
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
L.S.C.

FIG. 19.

Effect of Industrial Consumption in Increasing per Capita Consumption.

Striking evidence of the important influence of industrial uses of water upon the variation in per capita daily consumption of water in our American cities is furnished in two examples which recently came to the attention of one of the members of this committee.

The first example relates to the water consumption in a city in the heart of the Pennsylvania coal district. The water consumption was found to be 144 gal. per capita per day with a population of approximately 150 000 in the portion of the district covered by these works. Analysis showed, however, a leakage or amount of water-unaccounted-for of approximately 33 per cent., an average consumption of 89 gal. per day by each of the 28 000 consumers, and 17 gal. per day per capita. Most important of all, the domestic consumption was found to be but 18 per cent. of the total water-accounted-for, the remaining 82 per cent. being industrial consumption. Thus while the controlling Venturi meters indicated an average per capita consumption of 144 gal. per day, the domestic consumption was but 17 gal., the industrial consumption 79 gal., and the leakage or water-unaccounted-for, 48 gal. per capita per day.

In the other instance, that of the Champaign and Urbana Water Works (Illinois), the following approximate figures were found.

TABLE 47.

ESTIMATED WATER CONSUMPTION OF CHAMPAIGN AND URBANA, ILL.
(For the Year ending April 1, 1912.)

	Million Gallons during Year.	Per Cent. of Total.
Through large industrial meters, Champaign	13.7	3
Through large industrial meters, Urbana	75.1	14
Through small domestic meters, Champaign	96.1	17
Through small domestic meters, Urbana	48.2	8
By 641 flat-rate consumers at 600 g.p.d., estimated	110.4	20
By-passed at pumping station	18.0	4
Flush tank consumption	6.7	1
Total water accounted for by consumption and waste	368.2	67
Water-unaccounted-for (=33 per cent. of 550 Mg.)	182.0	33
Total water pumped in 1911	550.0	100

TABLE 48.

DOMESTIC WATER CONSUMPTION PER CAPITA AND PER CONSUMER OR FAMILY IN CHAMPAIGN AND URBANA.
(For the Year ending April 1, 1912.)

Place.	Estimated Population, Including Students.	Number of Domestic Consumers.	Metered Domestic Consumption in Gal. per Day.		
			Total.	Per Consumer.	Per Capita.
Champaign	......	2 045	263 000	129	....
Urbana	......	1 201	132 000	110	....
Total	27 600	3 246	395 000	122	15.4

In other words, whereas the average daily pumpage of water amounted to 55 gal. per capita, the actual domestic use of water amounted to but 15 gal. per capita per day.

Similar results are indicated by the following figures for the cities of Des Moines, Ia.; and New Orleans, La.

TABLE 49.

ANALYSIS OF TOTAL PUMPAGE, DES MOINES, IA., FOR YEAR ENDING DECEMBER 31, 1911.
(By courtesy of Mr. C. S. Denman.)

	Million Gallons.	Gallons per Capita per Day.*	Per Cent. of Total Pumpage.
1. Private Consumption:			
a. Metered (including schools and non-municipal public buildings)	1 068.0	32.5	55.4 per cent.
b. Unmetered (about 600 small consumers, estimated)	33.0	1.0	1.7 per cent.
Total	1 101.0	33.5	57.1 per cent.
2. Public Consumption:			
a. Public buildings (other than municipal) (included in 1*a*).			
b. Municipal buildings and engine houses (metered and unmetered)	6.4	0.2	0.3 per cent.
c. Street sprinkling and washing (included in 3*d*).			
d. Snow flushing, estimated	13.0	0.4	0.7 per cent.
e. Sewer flushing (included in 3*d*).			
f. Street construction work (included in 3*d*).			
g. Fire protection (included in 3*d*).			
h. Troughs and fountains (metered and estimated)	50.3	1.5	2.6 per cent.
i. Parks and cemeteries (metered)	9.2	0.3	0.5 per cent.
Total	78.9	2.4	4.1 per cent.
3. Operation Consumption:			
a. Slippage (included in 3*d*).			
b. Flushing mains (included in 3*d*).			
c. Leakage (included in 3*d*).			
d. 2*c*, 2*e*, 2*f*, 2*g*, 3*a*, 3*b*, and unaccounted for	748.1	22.8	38.8 per cent.
Total pumpage	1 928.0	58.7	100.0 per cent.

*Based on an estimated population of 90 000.

TABLE 59.

ANALYSIS OF DAILY CONSUMPTION OF WATER AT NEW ORLEANS, 1911.
(By courtesy of Mr. George G. Earl, superintendent of Water Works.)

	Million Gallons per Day.	Per Cent of Total.
Pay water to paying consumers	8.00	50.0
Free water to paying consumers	2.00	12.5
Under registration, paying consumers meters	1.00	6.3
Water used by free consumers, including 10 per cent. under registration of meters	1.12	7.0
Water used for all purposes at plants	0.20	1.2
Flushing sewers	0.07	0.4
Used through 5 000 fire hydrants for all purposes	2.00	12.5
Balance, leakage	1.61	10.1
Total	16.00	100.0

CONSIDERATIONS GOVERNING RECOMMENDATIONS OF THE COMMITTEE.

While data might be multiplied upon all of the factors suggested herein as influencing water consumption, and others not referred to, such as variation in water pressure, the facts adduced seem to justify a revision of the form for recording water consumption statistics now in use by this Association.

In outlining the suggested new forms, the committee, while recognizing the desirability of further subdivisions of water consumption than those recommended by it, has been constrained by the belief that the form of the record must be made as simple and ready of application as possible, in order to induce operators to make use of it and to analyze the conditions existing upon their works with sufficient care to attain substantial accuracy. In this way only is it believed to be possible to get a number of reports along the new lines sufficient for comparative purposes. Later, when the importance of accurate knowledge of water consumption, use, waste and leakage is more clearly recognized, further subdivision and analysis may prove feasible, as well as desirable.

LEONARD METCALF, *Chairman*,
FRANK J. GIFFORD,
WILLIAM F. SULLIVAN,
Committee.

[Discussion of this Report will be held until after the September meeting for publication with the Proceedings thereof.]

Equivalents of Various Measures.

	U. S. Gallons.	Imperial Gallons.	Liters.	Cubic Feet.	Cubic Meters.	Cubic Inches.	Pounds Avoirdupois (Water at 0° C.).
1 U. S. gallon...........	1.0	0.8311	3.78543	0.13368	0.003785	231.0	8.34545
1 Imperial gallon........	1.20032	1.0	4.54374	0.16046	0.004544	277.274	10.0172
1 Liter.................	0.26417	0.22008	1.0	0.03531	0.001	61.0234	2.20462
1 Cubic foot............	7.48052	6.23210	28.31700	1.0	0.028317	1 728.0	62.4283
1 Cubic meter..........	264.170	220.083	1 000.0	35.3145	1.0	61 023.4	2 204.62
1 Cubic inch............	....	....	....	....	....	1.0	0.036128

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, Mass., January 8, 1913.

The President, Mr. George W. Batchelder, in the chair.

The following members and guests were present:

Honorary Members.

F. W. Shepperd and F. P. Stearns. —2.

Members.

S. A. Agnew, Randolph Bainbridge, C. H. Baldwin, A. F. Ballou, F. A. Barbour, H. K. Barrows, G. W. Batchelder, C. R. Bettes, A. E. Blackmer, Dexter Brackett, E. C. Brooks, James Burnie, G. A. Carpenter, J. C. Chase, R. C. P. Coggeshall, W. R. Conard, H. R. Cooper, A. W. Cuddeback, G. W. Cutting, Jr., F. W. Dean, J. C. DeMello, Jr., John Doyle, E. R. Dyer, E. D. Eldredge, J. N. Ferguson, G. H. Finneran, F. F. Forbes, F. L. Fuller, F. J. Gifford, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, E. A. W. Hammatt, A. R. Hathaway, T. G. Hazard, Jr., Allen Hazen, J. L. Howard, A. C. Howes, J. L. Hyde, H. R. Horton, E. W. Kent, Willard Kent, G. A. King, J. J. Kirkpatrick, C. F. Knowlton, H. O. Lacount, C. A. Leary, Daniel MacDonald, F. A. McInnes, W. A. McKenzie, N. A. McMillen, H. V. Macksey, A. E. Martin, John Mayo, J. H. Mendell, F. E. Merrill, William Naylor, Leonard Metcalf, H. A. Miller, C. E. Peirce, T. A. Peirce, C. M. Saville, C. W. Sherman, M. A. Sinclair, J. W. Smith, G. A. Stacy, W. F. Sullivan, L. A. Taylor, R. J. Thomas, L. D. Thorpe, D. N. Tower, C. H. Tuttle, W. H. Vaughn, J. H. Walsh, F. P. Washburn, R. S. Weston, G. C. Whipple, T. H. Wiggin, F. B. Wilkins, G. E. Winslow. — 81.

Associates.

Builders Iron Foundry, by A. B. Coulters and D. W. Bartlett; Central Foundry Company, by J. H. Morrison; Chapman Valve Manufacturing Company, by R. Shirley and H. L. DeWolfe; Darling Pump and Manufacturing Company (Ltd.), by W. H. Peckersgill; *Engineering Record*, by R. K. Tomlin and I. S. Holbrook; Goulds Manufacturing Company, by R. E. Gould; Hersey Manufacturing Company, by A. S. Glover and W. A. Hersey; Kennedy Valve Company, by Mr. Brosnan; Lead-Lined Iron Pipe Company, by T. E. Dwyer; Chas. Millar & Son Co., by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Pittsburgh Meter Company, by J. W. Turner; Platt Iron

Works Company, by F. H. Hayes; Rensselaer Valve Company, by C. L. Brown and F. S. Bates; Standard Cast Iron Pipe and Foundry Company, by Wm. Woodburn; Union Water Meter Company, by F. E. Hall; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison; A. P. Smith Manufacturing Company, by D. F. O'Brien. — 30.

GUESTS.

Milton Thorne, Portland, Me.; R. Suter, Albany, N. Y.; Master James Kintoch, East Greenwich, R. I.; M. L. Fuller, Brockton, Mass.; Frank I. Hall, Middletown, Conn.; Ivers M. Low, Weymouth, Mass.; J. Griffin, Middletown, Conn.; Professor Carpenter, Ithaca, N. Y.; Charles R. Gow, Boston, Mass.; and D. J. Higgins, Waltham, Mass.; Mr. Grove and Mr. Marks, of Washington, D. C. — 12.

The Secretary read the records of the December meeting, and they were approved.

The Secretary presented applications for active membership, properly endorsed and recommended by the Executive Committee, from Milton Thorne, Portland, Me., engaged in construction work, Portland Water District; Russell Suter, Albany N. Y., with the New York State Water Supply and Conservation Commission; John S. Potter, State Highway Commission of Minnesota, assistant engineer at large; Richard Winslow Sherman, Utica, N. Y., chief engineer New York State Conservation Commission; J. C. Rickards, Canton, N. C., superintendent Canton Water Works; John D. Moore, with the New York State Conservation Commission.

On motion of Mr. Edwin C. Brooks, the Secretary was directed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

The Secretary, Mr. Willard Kent, presented his annual report as follows:

REPORT OF THE SECRETARY.

JANUARY 1, 1913.

Mr. President and Gentlemen of the New England Water Works Association, — In accordance with the Constitution, the Secretary submits herewith the following detailed statement of the changes in membership in the several grades for the past year.

MEMBERSHIP.

January 1, 1912.	Honorary Members	12			
January 1, 1913.	Honorary Members				12
January 1, 1912.	Total Members		680		
	Withdrawals:				
	Resigned	23			
	Dropped	30			
	Died	9	62		
		—	—	618	
	Initiations:				
	January	6			
	February	10			
	March	2			
	June	10			
	September	5			
	November	2			
	December	4			
		—	39		
	Reinstated:				
	Nine members reinstated in 1912		9	48	
			—	—	666
January 1, 1912.	Total Associates		58		
	Withdrawals:				
	Resigned	4			
	Dropped	4	8		
		—	—	50	
	Initiations:				
	March	1			
	September	2		3	53
January 1, 1913.	Total membership				731

The Secretary has received $6 650.89, which has been paid to the Treasurer, and has certified for payment, bills amounting to $4 463.10.

There is due the Association at this date —

For Reprints	$5.25
,, Journals	8.00
,, Advertisements	53.75
,, Standard Specifications	7.20
Total	$74.20

I know of no outstanding bills against the Association other than those for the December issue of the Journal not yet presented.

A statement of the receipts, expenditures, accounts receivable, and bills payable will be found in detail in the report of the Treasurer.

Respectfully submitted,

WILLARD KENT, *Secretary.*

Year.	President.	Membership at End of Year. Members.	Associate.	Honorary.	Total.	Annual Convention. Place.	Date.	Receipts.	Expenditures.	Cash Balance.
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 701.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.91	2 271.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.21
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	*Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	692	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	†4 566.81	‡3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	†7 237.60	‡2 719.05
1911	Allen Hazen	680	58	12	750	Gloucester, Mass.	Sept. 13–15, '11	6 440.90	†6 279.72	‡2 880.23
1912	Geo. W. Batchelder	666	53	12	731	Washington, D. C.	Sept. 18–20, '12	6 861.65	†5 934.56	‡3 807.32

* Deceased. † Not including December Journal and reprints. ‡ Does not include $1 81[illegible]

Mr. R. C. P. Coggeshall. Do I understand from the report that during the past year there has been a net loss in the membership?

The Secretary. A year ago the total membership was 750, and to-day it is 731.

Mr. Coggeshall. That is, we are 19 shy from a year ago?

The Secretary. Rather more than the usual number, I think, have withdrawn by resignation during the year, and 30 members have been dropped.

Mr. Coggeshall. In preceding years we have usually shown a small gain each year?

The Secretary. We have usually shown a small gain.

On motion of Mr. Coggeshall it was voted that the report of the Secretary be accepted, placed on file, and printed in the Journal.

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report:

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$214.11
Initiation fees	$197.00	
Dues	2 866.50	
Total received from members		3 063.50
Journal:		
Advertisements	$1 838.75	
Subscriptions	213.00	
Sale of Journals	266.19	
Sale of Reprints	149.80	
Total received from Journal		2 467.74
Miscellaneous receipts:		
Sale of "Pipe Specifications"	$40.90	
Dinners	670.50	
June Excursion	404.90	
Total miscellaneous receipts		1 116.30
Total receipts		$6 861.65

Expenditures.

JOURNAL:			
Advertising agent, commission		$250.00	
Plates		70.97	
Printing		1 215.11	
Editor's salary		300.00	
Expense		30.99	
Reporting		265.10	
Reprints		197.25	
Envelopes		28.50	
			$2 357.92
Office:			
Secretary, salary		$250.00	
Expense		62.82	
Assistant Secretary, salary		600.00	
Expense		159.11	
Rent		500.00	
Printing		65.50	
Membership lists		191.00	
Stationery		94.22	
Envelopes and postage		113.50	
Library		6.50	
Miscellaneous		6.75	
			2 049.40
Meetings and Committees:			
Stereopticon		$50.50	
Dinners	$689.00		
Cigars	46.30		
Music	75.00		
		810.30	
Badges		47.39	
Printing and postage		159.75	
			1 067.94
Treasurer's salary and bond			67.50
June Excursion			373.00
Miscellaneous expenses			18.80
			$5 934.56

On motion of Mr. Edwin C. Brooks, it was voted that the report of the Treasurer be accepted, placed on file, and printed in the JOURNAL.

Lewis M. Bancroft, Treasurer,
In account with the New England Water Works Association.

RECEIPTS.			EXPENDITURES.		
1912.			Bills paid		$5 934.56
Jan. 1.	Balance on hand	$2 880.23	BALANCE ON HAND.		
	Received of Willard Kent, Sec'y	6 650.89	People's Savings Bank	$1 950.28	
	Interest on bonds and deposits	210.76	Mechanics Savings Bank	1 014.98	
			First National Bank	607.52	
			Liberty Trust Co.	234.54	
					3 807.32
		$9 741.88			$9 741.88

ASSETS AND LIABILITIES.

ASSETS.			LIABILITIES.	
Cash, balance in banks		$3 807.32	Accounts payable:	
Bonds Nos. 2642 and 2644 Lake Shore & Mich. So. R. R. 4%, due May 1, 1931. Book value, $1 815. Market value		1 850.00	Editor's salary	$75.00
Accounts receivable:			Reprints	55.75
Reprints	$5.25		Plates	59.17
Journals	8.00		Printing	77.00
Advertising	53.75			$266.92
Specifications	7.20		Surplus	5 464.60
		74.20		
		$5 731.52		$5 731.52

Reading, January 7, 1913.

LEWIS M. BANCROFT, *Treasurer.*

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 8, 1913.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1912.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1912, and which are consequently not included in the Treasurer's statement); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat smaller in total pages and pages of text than that of several preceding years.

Illustrations. — The total cost of illustrations for the year, including printing, has been $249.64, or 10 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge, and additional reprints, when desired, at the cost of the paper and press work. The net cost to the Association for reprints has been $91.45. There have been advance copies of four papers prepared during the year at a cost of $35.50.

Circulation. — The present circulation of the Journal is:

Members, all grades	731
Subscribers	69
Exchanges	26
Total	826

a decrease of 14 over the preceding year. Journals have also been sent to 48 advertisers.

Advertisements. — There has been an average of 25 pages of paid advertising, with an income of $1 731.25, a slight decrease over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $40.90 have been sold; none were printed during the year. The net gain up to a year ago had been $214.05, so that the total net gain from this source to date is $254.95. There are still about 113 copies of specifications on hand, or about $11.30 worth if sold at retail.

The Association has a credit of $4.09 at the Boston Post-Office, being the balance of the money deposited for payment of postage upon the Journal at pound rates.

There are no outstanding bills, on account of the Journal, which are not included in these tables.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

Statement of Material in Volume XXVI, Journal of the New England Water Works Association, 1912.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Membership Changes.	Index.	Advertisements.	Cover and Contents.	Inset Plates.	Total.	Total Cuts.
1	March	59	53	112	. .	. .	30	4	2	148	8
2	June	55	5	60	. .	. .	30	4	6	100	13
3	September	114	18	132	2	. .	30	4	4	172	6
4	December	90	7	97	. .	6	30	4	10	147	26
	Total	318	83	401	2	6	120	16	22	567	53

TABLE No. 2.

Receipts and Expenditures on Account of Volume XXVI, Journal of the New England Water Works Association, 1912.

Receipts.		*Expenditures.*	
From advertisements . . .	$1 731.25	For printing Journal . .	$1 162.95
From sale of Journal . .	266.19	For printing illustrations .	119.50
From sale of reprints . . .	167.30	For preparing illustrations,	130.14
Subscriptions	213.00	For editor's salary	300.00
		For editor's incidentals . .	37.86
	$2 377.74	For advertising agent's commissions	246.25
Net cost of Journal . . .	98.81	For adv. agent's incidentals	2.00
		For reporting	183.60
		For reprints	258.75
		For advance copies . . .	35.50
	$2 476.55		$2 476.55

TABLE No. 3.

Comparison between Volumes XVIII to XXVI, Inclusive, Journal of the New England Water Works Association.

	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.	Vol. XXV. 1911.	Vol. XXVI. 1912.
Average edition (copies printed)	900	900	900	1 085	1 000	1 000	1 150	1 000	1 000
Average membership	596	625	665	693	699	710	732	752	740
Circulation at end of year	667	705	767	785	780	802	827	840	826
Pages of text	491	587	495	500	500	459	643	475	401
Pages of text per 1 000 members	824	939	745	722	715	646	880	632	542
Total pages, all kinds	794	784	662	669	681	627	808	654	567
Total pages per 1 000 members	1 332	1 254	995	964	976	884	1 090	870	766
Gross Cost:									
Total	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15	$3 490.81	$2 625.87	$2 476.55
Per page	3.69	4.17	3.88	3.95	4.01	4.97	4.32	4.02	4.37
Per member	4.91	5.23	3.87	3.82	3.91	4.39	4.78	3.50	3.35
Per member per 1 000 pages	6.18	6.67	5.85	5.70	5.88	7.00	5.90	4.09	5.90
Per member per 1 000 pp. text	10.00	8.91	7.81	7.62	8.02	9.56	7.44	7.36	8.35
Net Cost:									
Total	$648.11	$1 072.95	$387.96	$483.15	$131.06	$789.98	$1 334.06	$352.82	$98.81
Per page	.82	1.37	.58	.72	.19	1.26	1.65	.54	.17
Per member	1.09	1.72	.58	.70	.19	1.11	1.82	.47	.13
Per member per 1 000 pages	1.30	2.20	.88	1.04	.28	1.78	2.25	.55	.23
Per member per 1 000 pp. text	2.22	2.93	1.18	1.39	.39	2.43	2.83	.98	.33

On motion of Mr. R. C. P. Coggeshall, it was voted that the report of the Editor be accepted and printed in the JOURNAL.

REPORT OF THE AUDITING COMMITTEE.

The Auditing Committee submitted the following report:

BOSTON, MASS., January 7, 1913.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

Respectfully submitted,

ALBERT L. SAWYER,
JOHN W. MORAN,
Auditing Committee.

On motion of Mr. E. C. Brooks, it was voted that the report of the Auditing Committee be accepted, placed on file, and printed in the JOURNAL.

REPORT OF COMMITTEE TO PREPARE A STANDARD SPECIFICATION FOR FIRE HYDRANTS.

JANUARY 8, 1913.

To the New England Water Works Association. — As suggested at the January, 1912, meeting of the Association, the committee arranged for a conference with the manufacturers, and to this conference the committee from the American Water Works Association, also the National Fire Protection Association, were invited. The meeting was held on May 8, and all of the parties above mentioned were represented with the exception of the American Water Works Association.

An agreement was reached on most of the points under discussion, but regarding the matter of the size of the valve opening, the manufacturers considered that more data as to the friction losses in present commercial hydrants should be obtained than was available from the tests which the committee had made during the previous year on the few hydrants which they had been able to get from outside sources.

The manufacturers agreed to furnish such hydrants as the committee desired for this further work, and later a list of hydrants was prepared which it was considered would represent the present commercial product.

Excellent testing facilities were arranged for by Mr. F. A. McInnes, a member of the committee, and the tests were carried out during the fall. Five manufacturers furnished sample hydrants, three of each make.

The working up of the data for the tests of these fifteen hydrants, however,

has but just been completed, and not in time to be considered by the committee in conference with the manufacturers before this meeting of the Association.

A final conference of the several committees previously mentioned and the manufacturers is to be called soon, after which the committee will be ready to report its final conclusions to the Association.

It is believed that some headway has been made during the past year, and, therefore, this report is to-day submitted as one of progress.

Respectfully,

H. O. LACOUNT, *Chairman.*

THE PRESIDENT. If there is no objection on the part of the members present, we will continue the committee. It seems to be doing good work. Next is the report of the Committee "to Look After and Keep Track of Legislation and Other Matters Pertaining to the Development and Utilization of the Natural Resources of the Country." Mr. M. N. Baker is chairman of the committee. Is there any one here who represents the committee?

THE SECRETARY. Mr. Baker writes that he cannot be present at the annual meeting and asks that I submit to the Association the following report:

REPORT OF THE COMMITTEE "TO LOOK AFTER AND KEEP TRACK OF LEGISLATION AND OTHER MATTERS PERTAINING TO THE CONSERVATION, DEVELOPMENT, AND UTILIZATION OF THE NATURAL RESOURCES OF THE COUNTRY."

Your committee has nothing to report on its own behalf. It transmits, for such action as the Association sees fit, a letter from Mr. Gifford Pinchot, written on the letterhead of the National Conservation Association, urging the New England Water Works Association to define its position as to an attempt which Mr. Pinchot says is being made to transfer ownership of the national forests of the United States to the several states.

I may add that your committee has not conferred on the subject, so the only opinion I can express is the personal one that the transfer would be a national misfortune. If the other members of the Association are of like opinion it would seem to be desirable (again speaking personally) for the Association to pass a resolution against the transfer and to send copies of the resolution to the persons mentioned at the close of Mr. Pinchot's letter.

M. N. BAKER, *Chairman*

December 31, 1912.

New England Water Works Association,

Mr. M. N. Baker, 220 Broadway, New York, N. Y.

My dear Sir, — I realize, at least in part, how great must be the pressure of current work before your organization. But in the light of the work your organization has done and is doing, and of the standards which govern it, I believe that the request that I am about to make will not be disregarded.

For several years a movement has been afoot to turn the national forests over to the states. This movement is now alert, organized, and active, and notice has been served in Congress that it will be pushed. Behind the movement are interests like the water power combines, eager to get public resources into their own hands for their own unregulated use, and which see no other way of accomplishing this result except by the easy road of state ownership and administration.

I need not say to you that once such a movement is afoot in Congress, it is a pressing danger until it has been met and overcome. I look upon the danger of the transfer of the national forests to the states as decidedly the most serious that has yet confronted the conservation movement.

There are two reasons against state ownership or state administration of national forests. The one is that it is impracticable upon the side of efficiency; the other is that it would make extremely difficult the protection of the national forests from graft.

The national forests, like the water powers, the timber, the grass, and the coal measures which they contain, are all resources essential to the national prosperity. They do not stop, and the use of them does not stop, at state lines. They can be used and developed and administered only under a central policy alive to their importance to the whole people, and not sensitive merely to their importance to any one section of the people. On the side of expense, state administration of the national forests would necessarily entail the greatly increased difficulty and cost of creating and maintaining many forest services instead of maintaining a single National Forest Service, and national forest users would pay the enormously multiplied cost. And it is well to remember that the time is rapidly coming when the products of the national forests will be little less important to those who live in the North and in the South than to those who live in the West. This is as true of beef and mutton, grazed in the forests, as it is of wood.

But the chief danger of this movement to turn over the national forests to the states is that under state ownership national forest resources, like water power, timber, and the land itself, would pass rapidly into unregulated private ownership and control. The best evidence of this danger is the story of how the Western states have administered their public lands; and there is a similar record in many Eastern states as well. Two billion dollars' worth of tangible resources, which is what the national forests are easily worth, offers large opportunities and large attractions to the grabbers. That is the chief danger of the movement to turn the national forests over to the states.

What I am led to ask is that your organization make its position clear in

this fight. You will know best how this might be done. If there is any way in which the attempt to break down the national forest system and the national conservation policy can be brought to the attention of your members, then I earnestly ask that this be done. It may be possible also for your organization to take up this matter in a resolution protesting against the proposed transfer to the states, a copy of which resolution might well go to the President, the presiding officer of the Senate, the Speaker of the House, as well as Senators and Representatives in Congress. Such action would be helpful in the highest sense in protecting the natural resources for all the people.

Sincerely yours,

GIFFORD PINCHOT.

The President. This report by Mr. Baker shows progress, but is not final. If there is no objection the committee will be continued. Is there anything to be said about Mr. Pinchot's letter?

Mr. J. Waldo Smith. Mr. President, on a great many matters I am not at all in accord with Mr. Pinchot, but I do agree with him on this. It seems to me it would be a great mistake, and, perhaps, a great public misfortune, to have the public forest lands, now under the control of the government, split up and transferred to the various states. Such a thing could result only in divided responsibility, and, I believe, in a much less efficient administration. I would move that this matter be referred back to the committee with power to act, with the further statement that it is the sense of this meeting that the best interests of the people will not be served by a transfer of these forest lands to the states.

Mr. C. E. Peirce. It seems to me, Mr. President, that a resolution coming directly from the Association would be more effective than merely the action of the committee.

Mr. Smith. I will add to my motion that the committee be requested to draft a resolution to be reported back to the Association at the next meeting.

Mr. Peirce. That would meet my idea.

Mr. Smith's motion as amended was adopted.

The President. Report of Committee on "Water Consumption and Statistics Relating Thereto." Mr. Leonard Metcalf is chairman of that committee.

Report of Committee on Water Consumption and Statistics Relating Thereto.

Mr. Leonard Metcalf. The report of the committee is substantially in shape. It is, however, too long a document to present to the Association at this time, and the committee has, therefore, suggested to the Executive Committee that, if it deems the matter of sufficient interest to members of the Association, the report be assigned for discussion at some future meeting. The committee hopes that advance copies of this report will be prepared and sent out, and that members may find time to give the subject careful consideration, and that all who can will contribute to the data contained in the report, so that it may in fact be a symposium upon this subject.

We feel that we have been very fortunate in getting together certain data, as a result of the good-will and the courtesy of a number of different gentlemen who have contributed, particularly Mr. Brackett, who has given us some of the Metropolitan records which we think extremely valuable, and which have not yet appeared in print, at all events in the form in which they will appear in this report. Some of the tabulations which have resulted from the data submitted by the various members in answer to the circular which we sent out also give good new material. We hope that all of you will do what you can to fill in any missing places that you may find in the report.

The President. You have heard Mr. Metcalf's remarks, gentlemen, and if there is no objection I think it will be well to continue the committee until such time as the report is presented to the Association. Hearing no objection we will let the matter stand in that way.

Next is the report of the Committee "to Collect Information as to Low Water Yields of Catchment Areas in New England, and, at their Discretion, Outside of New England." Mr. Frederic P. Stearns is chairman of that committee.

Report of Committee to Collect Information as to Low Water Yields of Catchment Areas in New England, and, at their Discretion, Outside of New England.

Mr. Frederic P. Stearns. The committee has written this letter to the Secretary, which I will read:

January 7, 1913.

Mr. Willard Kent, *Secretary*,
New England Water Works Association,
715 Tremont Temple, Boston, Mass.

Dear Sir, — In its progress report dated September 14, 1912, the Committee on Yield of Drainage Areas expressed the hope that it might present its final report at the annual meeting in January, and it regrets that it is unable to do so.

Information regarding the yield of several additional streams for the years 1908–1911 inclusive has been received since September, completing all of the returns which the committee expects to receive, but four of these were received since the first of January, making it impracticable to report at the annual meeting.

Much work has been done since we last reported in working up the data received, and the necessary additional work will be done and a report prepared as promptly as possible.

Very truly yours,
FREDERIC P. STEARNS, *Chairman*.
H. K. BARROWS, *Secretary*.

I might add that since coming here I have been promised one more return which will be ready within a week, and the committee intends to close the matter up and bring things to a head at once.

The President. You have heard the report as presented by Mr. Stearns. If there is no objection the committee will be continued until such time as its final report is ready. The chair hears no objection.

Report of Committee on "Standard Specification of Cast-Iron Pipe." Mr. F. A. McInnes is chairman of the committee.

Report of Committee on Standard Specification of Cast-Iron Pipe.

The Secretary. Mr. McInnes is unable to be present and has sent the following letter, which I will read:

BOSTON, MASS., January 8, 1913.

To the President and Members of the New England Water Works Association, — I beg to report on behalf of the Committee on Standard Specifications for water pipe that sufficient progress has not yet been made to warrant a detailed report at this time; we have made a good start and hope for substantial progress in the near future.

Very respectfully,

F. A. McINNES, *Chairman*

Committee on Standard Specifications for Water Pipe.

THE PRESIDENT. You have heard this report. I know from personal knowledge that the committee is doing valuable work, which takes a good deal of time. If there is no objection we will continue the committee with power until it is ready to present its final report.

The Secretary read the following letter:

BOSTON, January 8, 1912.

NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — Following the cold winter of 1911–12, President Batchelder suggested that the committee which had previously reported on the Depth of Laying Water Pipe might profitably seek to obtain additional data.

Accordingly, in March, 1912, the undersigned sent out seventy personal letters to superintendents and engineers located in parts of this country and Canada where it was believed that the conditions of the preceding winter might have developed interesting results.

Forty replies were received, but no information tending to change the earlier conclusions of the committee,* namely, that freezing in mains laid at the depth now generally adopted has not occurred, except in dead ends, and that where there is an assured circulation, depths somewhat less than present practice would be safe.

Respectfully submitted,

F. A. BARBOUR, *Chairman.*

Mr. Charles W. Sherman, principal assistant with Metcalf & Eddy, Boston, Mass., presented a paper entitled "An Experience with Water-Ram." Mr. Caleb M. Saville followed with a paper relating experience with water-ram which he had had in connection with the Hartford works. The subject was discussed by Mr. G. A. Caldwell, Mr. Francis W. Dean, Mr. John Doyle, Mr. Allen Hazen, Mr. Frank L. Fuller, and Mr. Charles E. Peirce.

Mr. Robert J. Thomas, superintendent, Lowell, Mass., read

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* JOURNAL N. E. W. W. A., Vol. 23 (1909), p. 435.

a paper on "The Water Works of the City of Lowell and Some Recent Improvements," illustrated by stereopticon views.

Mr. Batchelder, the retiring President, then made his address.

President's Address.

Gentlemen of the New England Water Works Association. — The time has arrived when your retiring President is to render an account of the affairs of the Association for the year 1912.

The reports of other officers so completely cover the ground there is little left for the President to say.

The year just closed has been typical of many others. Meetings have been held at the Brunswick Hotel during the months of January, February, March, November, and December.

The June outing of the Association took the form of a trip to the Cape Cod Canal, and was attended by 133 members and guests. A special train conveyed the party to Buzzard's Bay, where a part of the work could be seen, and the project was explained by one of the engineers in charge. Special electric cars were taken to Onset, where luncheon was served, after which the return trip to Buzzard's Bay carried the party to their special train which conveyed them to several stopping places where work was in progress. The trip back to Boston was a quick one, with hardly a stop, and brought to a close what was to the writer a delightfully cool and pleasant day.

The Annual Convention was held in Washington, D. C., September 18, 19, and 20, headquarters at the Congress Hall Hotel. There was a registration of 221 members and guests.

Several papers were read and discussed relating principally to the supervision and control of dams both in construction and operation. These papers were of great interest and treat of a subject which must be recognized as of great importance. The accommodations at the hotel were very satisfactory, the management showing an unfailing desire to please.

The following members have died during the year: C. A. Allen, December 9, 1912; T. C. Bates, January 11, 1912; D. S. Brinsmade, September 7, 1912; N. W. Hayden, January 29, 1912; G. A. Kimball, December 3, 1912; D. S. Merritt, March 8, 1912;

J. B. Putnam, May 8, 1912; Ulrich Taubenheim, January 8, 1912; C. K. Walker, September 9, 1912.

Former presidents of your Association have chosen many subjects for their addresses, so that the field for originality is narrowed. The subject of my brief paper to you to-day is, "The Public in Connection with the Administration of a Water Department."

In the development of water supplies great difficulties have to be overcome. To secure necessary appropriations often requires years of hard work and courage in the face of opposition, which frequently, through lack of knowledge of the conditions, succeeds in delaying work which is badly needed.

After appropriations are made the work progresses and in many cases a fine plant is put in operation, reservoirs of ample storage capacity are constructed, containing a supply of excellent water, a good pipe system is laid, the water rates are reasonable, and good service is given the consumers; but if the element of human interest is left out in the relations between the public and the management, the highest degree of efficiency cannot be attained.

The citizens of this country, as well as others, have an inborn doubt as to the fairness of public service corporations and municipal departments.

Who among us has not heard some story about the gas company, for instance, — how the owner's house was closed for weeks and a bill rendered him just the same, etc.

We have undoubtedly heard many worse ones about the departments we manage, and it sometimes appears as though many men think a bill rendered by a municipal department is either made larger than circumstances warrant or is downright robbery.

The best way to overcome that difficulty has been studied by the writer for several years, and it sometimes appears that study might go on forever, there constantly being a new crop of kickers born, but good results are worth hard work, and if advances are made, that gives sufficient encouragement to keep on.

To secure the confidence of the consumer is, in the writer's opinion, the key to the whole situation, and no better way can be found than by giving close personal attention to all complaints

and dealing with each one with perfect frankness. Attempts to fool the public are wrong in principle and poor in policy.

Every person who has a complaint to make about the service, a bill which has been rendered, or of anything in connection with the department, should be accorded a hearing, listened to courteously, and the matter carefully looked over.

If the consumer has a just complaint it should be fairly and promptly adjusted; if there is no mistake or fault in the service, an examination will reveal that fact, and the explanation will be satisfactory. This paper is intended to deal with the man who thinks he has cause for complaint, — not the dishonest man who wants something for nothing, or the bluffer who thinks a loud voice will win him something. There are other ways of treating people of that sort.

The most frequent cause of complaint against a water department is in the amount of the bill rendered for water at certain stated periods, and the writer asks the liberty of citing some of the things done in Worcester to satisfy or at least show a desire to look after the consumer's interests.

The water meters in Worcester are read monthly, each day's readings put on cards which are left in the office every morning. These readings are carefully gone over, an increase of ten to twenty per cent. over the previous reading is noted, and an inspector is dispatched to the premises.

His duty is to make an inspection of the fixtures to see if any leaks are in existence, and to go thoroughly over the whole proposition with a view of discovering the reason of the increase in the meter readings.

The detailed method of looking for leaks is, of course, familiar to you all and needs no explanation here.

When leaking fixtures are discovered, the owner receives a notice from the water office stating the nature and location of the leak, the amount of water being consumed, and he is advised to have the leak promptly repaired.

In case no leak is found, there may be other reasons why the consumption of water is excessive; if these can be discovered by the inspector, a report is made to the owner, and if no reason can be found, the owner is notified of the excessive use so he will be

aware of what is going on. Now, how does this work out? The fair-minded person when made to feel that his interests are being looked after, especially by a municipal department, is surprised and gratified. The man who would adopt sharp practice and seek a reduction in his water bill makes a very poor showing when confronted by evidence that continued and neglected leaks of which he had been notified were the cause of his large bill. The case of one large property owner will illustrate this point.

He had repeatedly been notified of a leaking water closet and had allowed it to continue for several months, with the inevitable result, a large water bill, amounting in this case to about $45 for a small two-family house. When the bill was rendered, and after waiting to the last day of grace, he called at the office and requested an abatement, which was refused, and the reasons given. He became abusive, but that seemed to have no effect, so he went on his way. Some days afterwards a call came from the mayor's office, and in answering that summons the writer met the gentleman with the large water bill. The mayor said the gentleman had a grievance and had appealed to him. The records were sent for and shown to his Honor, who without hesitation turned and said, "Mr. ————, you haven't a leg to stand on." So the appeal fell flat.

Another phase of the matter and the final chapter in the story came on the writer's way back to the department offices. He was accosted in a suggestive manner by the owner of the property, who in a voice scarcely above a whisper said, "Isn't there some way we can fix that up?" The writer replied in like voice and manner, "Yes." Whereupon the owner said, "How?" and he was told in good round English to "Go to the treasurer's office and pay the bill," which seemed to displease him greatly, as his manner and language immediately lost their calmness.

The practical result of the close observance of meter readings has been to completely change conditions in the Water Department offices after the water bills have been sent out.

Instead of crowds of people in the lobby, waiting to make complaints, listening to the other fellow's story, comparing notes, and knowing all that can be explained before reaching their own case, there is now hardly a ripple; occasionally some misguided mortal

who imagines he has been overcharged, wanders into the office, but his complaint is very mild and he is easily shown the error of his ways.

Requests for abatements have become infrequent and seldom have much kick back of them.

But the chief value of this system consists in educating the people up to the idea that the Water Department means to be fair and is making every reasonable effort to protect the interests of the water takers.

Care must be taken, of course, to prevent the easy-going customer from placing his complete interests in the hands of the municipality and expecting he need make no effort to look after his own affairs, and of course such individuals can be found.

Efforts are also made to look after all complaints of any nature whatever, and in the writer's opinion the expense incurred is a good investment.

Complaints are received at times about the condition of the water, and they should be carefully attended to.

It is the practice in Worcester to flush out the main pipes, through hydrants, in a systematic manner, this being especially true when dead ends occur, but notwithstanding this system, there are frequent complaints of bad water, which are attended to promptly and a special blowing out given.

One case in particular comes to the mind of the writer which shows the other side of the question. A lady whose property is located on a dead-end pipe line was frequent in her complaints of bad water, and the department cheerfully responded to her requests to have the line blown out, until one day in the hearing of one of the clerks in the Water Department she made the remark that "when the wind blew from the east the water at her house was always bad the next day, and she requested the department to blow out the water pipe."

Inasmuch as her home is located over nine miles from the reservoir and on the end of a large pipe line which would not be drawn out for several days, the writer did not respond enthusiastically to her next request.

But we find the general rule that close personal attention to complaints results in a good feeling between the department

and the consumers and is well worth all the time and expense involved.

In conclusion, gentlemen, let me thank you for the many courtesies shown me in the past year and for the honor of having served as your President.

The tellers appointed to canvass ballots submitted the following report:

Election of Officers.

Whole number of ballots	305
Blank	1

President.

J. Waldo Smith	294
Scattering	1

Vice-President.

Frank A. McInnes	291
Leonard Metcalf	295
William F. Sullivan	292
Millard F. Hicks	291
Caleb M. Saville	293
Samuel A. Agnew	292
Scattering	1

Secretary.

Willard Kent	296

Treasurer.

Lewis M. Bancroft	294

Editor.

Richard K. Hale	297

Advertising Agent.

George A. King	298

Additional Members of Executive Committee.

George A. Stacy	296
James L. Tighe	295
James W. Blackmer	295

Finance Committee.

Albert L. Sawyer	295
John W. Moran	293
John C. Chase	295
Scattering	1

Respectfully submitted,

GEORGE H. FINNERAN.
ARTHUR F. BALLOU.

Addressing Mr. Smith, the newly elected President, the retiring President said: "You having been elected President for the year 1913, allow me to congratulate you and the Association on your election."

Mr. Smith then took the chair and said: Allow me to congratulate our retiring President on the completion of a very successful administration.

Friends and members of the New England Water Works Association, I thank you for this great and unexpected honor. To be frank with you at the start, I want to say that I have coveted this job for a long time, and I am now experiencing the joy which always comes with accomplishment. Born and brought up in Massachusetts, one of the older members of the Association, I think I may say, although I have wandered abroad and fed in strange pastures, I am glad to come home and to be one of you again.

This Association, the oldest of its kind, I think, can look back on many years of effective and successful work. It has been from the start essentially an association of water-works superintendents, — hard-headed, practical men, with an unusual endowment of good judgment, who have learned what they knew from personal, intimate contact with their work. In these days of specialization and more intricate conditions, the engineer has come in to help, but the Association is to-day, as it always has been, essentially one of water-works superintendents. And I am particularly pleased that I can qualify from that standpoint, perhaps not from my present work, but from past experience, — first at Lincoln, Mass., as fireman and engineer, in the repair gang, in the operating force, and later in Paterson, N. J., and I hope, if my good fortune continues, that I will again join the operating and maintenance force.

With the cordial and earnest coöperation of the officers and members of the Association it will be my aim during the coming year to maintain and advance the high standard which my predecessors have set. I thank you, gentlemen. [*Applause.*]

On motion of Mr. Coggeshall it was voted to adjourn.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at the rooms of the Association, Tremont Temple, Boston, Wednesday, January 8, at 11.30 A.M.

Present: President George W. Batchelder, and members J. Waldo Smith, Randolph Bainbridge, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

Six applications for membership were received, viz.: Milton Thorne, Portland, Me.; Russell Suter, Albany, N. Y.; John S. Potter, assistant engineer, State Highway Commission, St. Paul, Minn.; Richard Winslow Sherman, chief engineer, New York State Conservation Commission, Albany, N. Y.; J. C. Richards, Canton, N. C.; John D. Moore, Conservation Commission of the State of New York, Albany, N. Y., and the applicants were by unanimous vote recommended for membership.

A letter from Mr. Gifford Pinchot, with reference to conservation legislation, was presented, and Mr. J. Waldo Smith was instructed to present a motion at the meeting of this Association to the effect that the Committee of this Association on Conservation be duly authorized to act in the matter.

Adjourned.

WILLARD KENT, *Secretary.*

New England Water Works Association.

ORGANIZED 1882.

Vol. XXVII. June, 1913. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

AN EXPERIENCE WITH WATER RAM.

BY CHARLES W. SHERMAN, PRINCIPAL ASSISTANT ENGINEER, METCALF & EDDY, CONSULTING ENGINEERS, BOSTON, MASS.

[*Read January 8, 1913.*]

About three years ago the Northeast Harbor Water Company, experiencing some difficulty on account of the fluctuations of pressure resulting from the operation of a hydraulic elevator in a summer hotel, served notice upon the proprietor that he must install tanks to supply the elevator instead of taking the water directly from the main pipes. The proprietor felt that the demand was unreasonable, and demurred, whereupon the company notified him that they would cut off his water unless he complied with their requirements. Upon this the proprietor brought suit in equity to enjoin the company from cutting off his supply of water. The case was heard in April, 1910, and the result is briefly stated in the following quotation from the *Engineering Record* of March 11, 1911.

"Water for elevators has proved a source of so much contention between water-works superintendents and consumers that a decision by the Maine Supreme Judicial Court in Kimball *v.* Northeast Harbor Water Company, 78 Atl. Rep. 865, deserves attention. The company requested the plaintiff to modify his hydraulic elevator connection in such a way that the water from an 8-in. street main would first pass into a tank through the 4-in. service, instead of directly to the elevator mechanism. The company pressed this request, and as an answer to it the plaintiff brought a bill in equity to restrain the company from shutting off its supply. The Court decided that the use of water for a

hydraulic elevator was a domestic use, within the ordinary meaning of charters to water companies authorizing them to furnish supplies for domestic uses. On this ground it ruled that the company was obliged to furnish water for a hydraulic elevator, if the plaintiff so desired. On the other hand, the Court ruled that the company was justified in asking the plaintiff to build tanks of sufficient capacity to relieve the street mains from the water hammer and other inconveniences caused by operating the elevator directly. These troubles are well known to superintendents, particularly those who have attempted to furnish water under rather high pressure for such purposes. The Court held that the company's request was clearly justified and that no one could successfully maintain that its obligation as a public service corporation to other consumers, as well as a proper regard for the protection of its own property, did not warrant its request. The Court accordingly refused to grant the injunction, leaving the company free to cut off service to the property in question unless the owner made some reasonable provision for operating the elevator."

The writer testified as an expert for the plaintiff, and made some tests in preparation for his testimony, the results of which may be of interest, as well as the principal figures submitted by the Water Company, showing the actual results of the operation of the elevator in question.

The conditions were roughly as follows: The hotel was supplied by a 4-in. pipe, 300 or 400 ft. long, leading from an 8-in. main supply pipe at a distance of some two or three miles from the pond from which the supply is taken. The hydraulic elevator — the only one in town — is of an old type and has a total lift of about 32 ft. The travel of the plunger is about 4 ft., and its diameter is 22 in. It was found that the elevator valve was made to open or close a series of holes, with the intention of making the opening or closing rather slow; and that it was necessary to overhaul 4.5 ft. of valve rope to open or close the valve, or 9 ft. to reverse the elevator. The static pressure at the hotel was about 40 lb. per sq. in., and a relief valve set at 45 lb. had been installed near the elevator.

Nobody seemed to know just how long it took the elevator to make a trip, but it was conceded that it could hardly have been less than 30 sec. Assuming this to be correct, the 22-in. plunger

traveled about 4 ft. (and consequently the displacement was 79 gal.) in 30 sec., or the flow was 158 gal. per min., corresponding to a velocity of less than 3 ft. per sec. in the 4-in. pipe, which is certainly not an excessive velocity. If this could have been checked instantaneously the resulting water ram would have been considerable, but it would obviously have required an appreciable time to overhaul 4.5 ft. of valve rope to shut off the water.

The data available before the Water Company had presented its case were not sufficient to enable the writer to make an estimation of the increased pressure which might have resulted from the operation of the elevator, to which he would care to testify. In order to get some information which might serve as an indication, an experiment was made, through the courtesy of the superintendent of the water works at Ellsworth, where the court was in session. Here a place was found where there was a 4-in. pipe, some 400 ft. long, supplying a locomotive standpipe, where the normal pressure was about 68 lb. This branch, like that at Northeast Harbor, was from an 8-in. main leading from the reservoir at a considerable distance. No method was discovered of drawing water, or of opening and closing the valve, at the same speed as with the elevator, so it was determined to make the test as severe as possible. The pressure gage was attached to a house service pipe about 150 ft. from the locomotive standpipe, and the standpipe valve was opened wide, as rapidly as possible, left open until a condition of steady flow was obtained, and then closed as rapidly as possible. The maximum velocity in the 4-in. pipe is estimated to have been not less than 10 ft. per sec. The time of opening the 4-in. valve was 30 sec., and the time of closing was 20 sec. The pressure dropped almost immediately upon starting the valve from 68 to 28 lb., or to 41 per cent. of the normal; and at the instant of closing the pressure gage registered 134 lb., or 202 per cent. of the normal.

This maximum pressure is not great enough to be dangerous to any well-constructed pipe system, although the sudden fluctuations would doubtless be annoying at times.

The officers of the Water Company presented gage readings showing what the actual fluctuations had been in various parts of

town. The significant figures, as taken down during the testimony, are as follows:

PRESSURES OBSERVED AT VARIOUS PLACES IN NORTHEAST HARBOR DURING OPERATION OF HYDRAULIC ELEVATOR.

Pounds per Square Inch.			Per Cent. of Normal.	
Normal.	Highest.	Lowest.	Highest.	Lowest.
56	75	40	135	71
58	60	35	104	60
55	62	32	112	58
32	40	10	126	31
32	50	10	156	31
60	80	40	133	67
58	85	35	147	60
55	75	35	136	63
54	70	25	128	46
51	70	28	137	55
30	50	10	167	33
30	50	8	167	27
28	60	10	213	35

The foregoing figures show that in general the operation of the elevator caused a drop in pressure ranging from 40 per cent. to between 60 per cent. and 70 per cent. when the valve was opened, and an increase in pressure, or water ram, amounting to from 30 per cent. to 50 per cent. of the normal pressure under ordinary circumstances, and sometimes running up to about 100 per cent. increase in pressure.

These results confirm in a general way the conclusions reached by the writer from the experiment described above, — that the pressure might drop about 60 per cent. below normal when the valve was opened, and rise to a maximum of about 100 per cent. above normal at the moment of closing the valve. These fluctuations are sufficient to cause annoyance, but, where the normal pressures are as low as in the cases cited, should not be dangerous to the pipes.

None of these results can be applied to conditions differing materially from those quoted above, but they may serve to give some indication of the extent of the water hammer that may be experienced in a small water-works system from the rapid closing of valves or fire hydrants.

The writer must not be misunderstood as in any way favoring the operation of hydraulic elevators directly from the street main, as a general proposition, as he fully realizes the annoyance, and in many cases, the danger, of such conditions. This particular case seemed to him one where the danger was slight, whatever the annoyance may have been.

DISCUSSION.

S. L. BERRY, ESQ.* (*by letter*).† Reference to Fig. 1 (p. 176), constructed from the formulæ given by Joukowsky, shows that the added pressure in the case of a 4-in. pipe, or a cast-iron pipe 0.48 in. thick, with the water flowing 4 ft. per sec. (for 158 gal. per minute) would be 235 lb. per sq. in. for a valve closure within the time required for the pressure wave to reach a free surface, of large size, and return. In the case of a water-supply system, this time would be difficult to predict, but every enlarged section reached by the wave would reflect pressure relief in accordance with the ratio of its area and physical conditions affecting the velocity of propagation of the wave to those conditions in the pipe in which the ram originated. As the velocity of propagation is, in this case, about 4 370 ft. per sec., the time required for the wave to return from the 8-in. main is 0.183 sec., and at this instant there would be a partial relief of the ram pressure. If the valve is closed in this time the full pressure of 235 lb. would be felt at the valve.

An interconnected system gives very complicated results as far as water hammer is concerned. The primary and most effective remedy is in slow operation of valves. Where this cannot be controlled, relief valves prevent undue ram pressures but have no effect on pressure drop, while air chambers at, or near, the valves minimize both conditions. These are, however, uncertain as to

* San Francisco, Cal.

† Addressed to the Editor of *Engineering Record*.

maintenance of air supply. In general, it may be said that any increase in elasticity in the system, at and near the valve, will decrease the severity of both variations from normal pressure. A central air vessel would tend to prevent extension of the ram to the entire system, but would have no effect upon the neighboring parts when a valve is suddenly closed.

The test conditions at the locomotive standpipe, while showing what was desired in this case, were such that no conclusions can be drawn as to the added pressure in the 4-in. pipe. The diagram before mentioned shows this to be, for a velocity of flow of 10 ft. per sec., 585 lb., for sudden closing within the limits given above. On the arrival of the wave at the 8-in. pipe, this would drop to about 270 lb. and would be reflected to the valve, arriving there 0.183 sec. after closing.

If the 4-in. pipe ran to a reservoir two miles away, the ram for a closure in 20 sec. would be about 125 lb., while for the 4-in. and 8-in. it would be materially less, probably 50 to 60 lb. The gage, being on a small pipe and probably near a dead end, would show a higher pressure than would exist in the 4-in. pipe. If the gage stood at 28 lb. when the closing began, the ram was 106 lb. at that point.

The whole subject of water hammer is most interesting and complicated, and there is a great need for extensive investigation and experiment.

The following is taken from a recent article * by the writer:

When the valve in a pipe line or the regulating mechanism of a water wheel is closed, partly or fully, a decreased velocity and an excess pressure result, the amount of which depends upon the velocity which has been lost, the degree of compression which the water undergoes, and the stretch in the pipe. This increased pressure wave starts at the valve, travels up the pipe with a velocity equal to that which sound would have under similar conditions, and which is dependent upon the same factors which control the ram pressure. In fact, the pressure is calculated directly from the velocity of the wave.

In a pipe line having no safety valves or air chambers, and consisting of pipe of the same diameter and thickness of wall through-

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* *Western Engineering*, Vol. 1, p. 713.

out the entire length, the pressure wave travels to the reservoir, where it drops to normal, and a wave of normal pressure travels toward the valve at the same velocity. On reaching this point, the pressure drops below normal by an amount somewhat less than the ram, and a wave of subnormal pressure runs to the reservoir and back. In this simple case a gage at the valve, if so made that it shows the pressures accurately, would rise to the ram pressure and stay there until the wave returned, when it would drop below normal for an equal time. The time of each of these cycles is found by dividing twice the pipe length by the velocity of the wave.

It is necessary to know this when determining the time within which the governor shall close the gates for the reason that it has been found that if the gates are closed before the pressure wave returns, the ram is as heavy as though they had been closed instantaneously. Thus long lines are more difficult to control than short ones, and anything which increases the elasticity of the line increases the time of the cycle, although it also decreases the amount of the supernormal pressure.

With varying diameters and wall thicknesses of pipes, the wave velocity and amount of pressure will be different in each section, and it is necessary to consider them in conjunction to obtain correct results. The pressure conditions at the valve become too involved to be followed very far, but it can be stated that in most if not all installations the lower section produces the most ram. As this influence extends upward, it is necessary to see that the thinner upper walls are not overstrained. If it is found from the diagrams that the lower section will be subject to a ram pressure of 400 lb. and the next, if considered by itself, to 300 lb., the resultant to which the one will fall and the other rise will be found between the two. This may be taken at approximately 350 lb. where the diameters do not vary greatly. Similarly, in the third section, this pressure of 350 lb. will increase the pressure which the section would have to withstand were it not influenced by conditions below it. It is seen that high velocities and rigid pipes below affect the safety of the lighter portions.

There will be a successive dropping of the pressure at the valve as the influence of the upper sections is felt, but the manner of

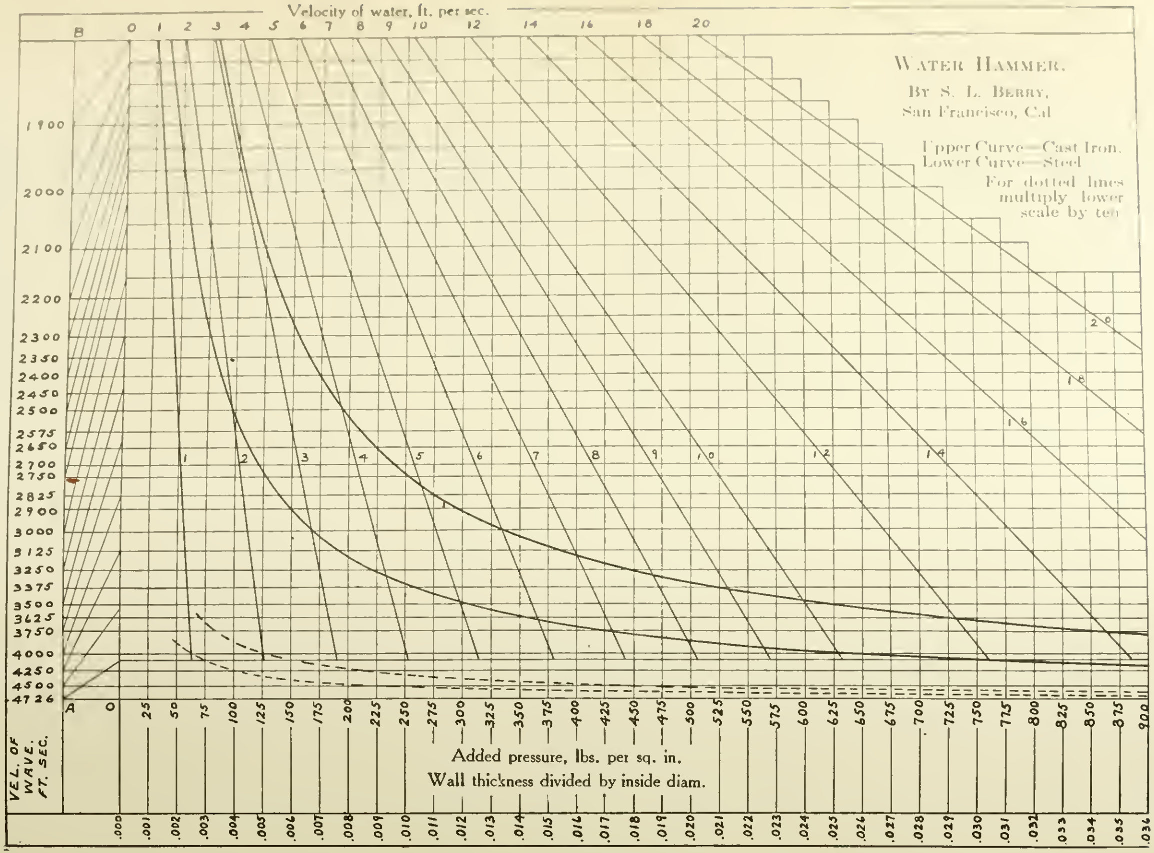

FIG. 1.

Divide wall thickness by inside diameter. Enter table with this figure at bottom. Follow vertically to curve, then to left to "Velocity of wave," then upward along the diagonal line and horizontally to intersection with "Velocity of water," then downward to "Added pressure." The dotted lines are continuations of those above, and in using them the scale of "Wall thickness divided by inside diameter" must be multiplied by 10, all other scales remaining unchanged.

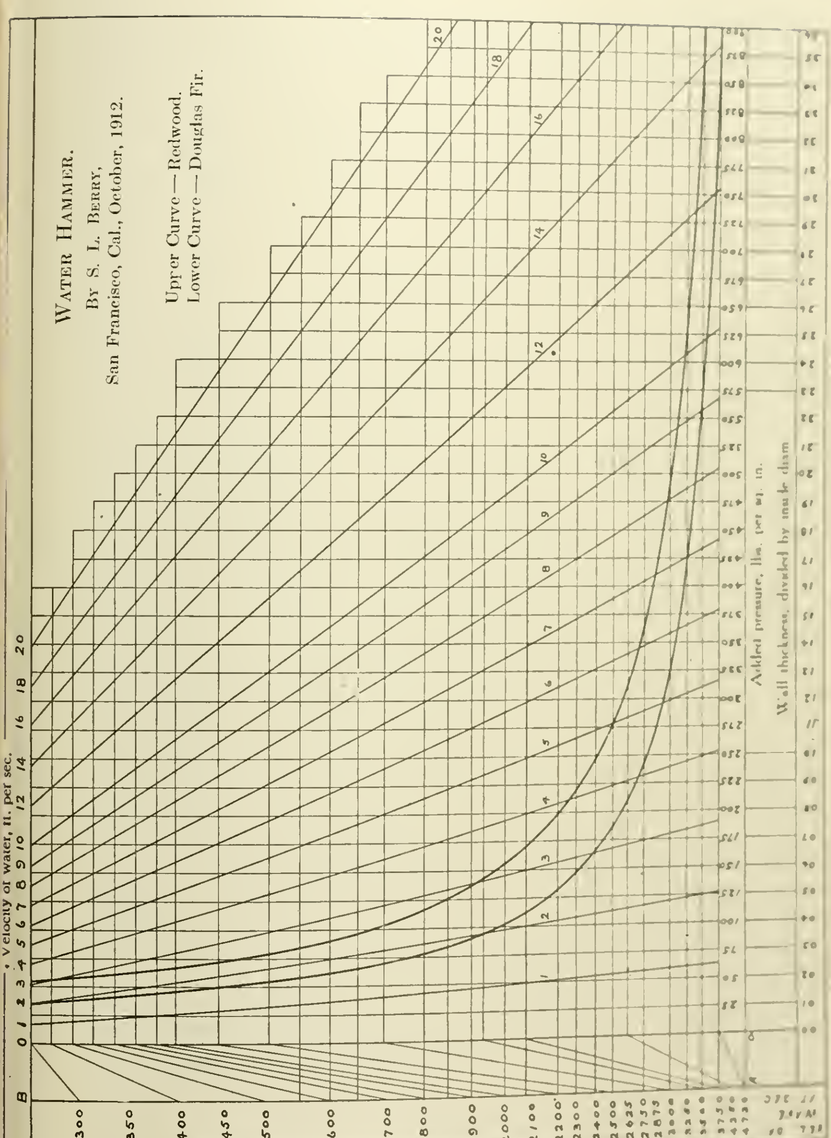
WATER HAMMER.
BY S. L. BERRY,
San Francisco, Cal., October, 1912.
Upper Curve — Redwood.
Lower Curve — Douglas Fir.
Velocity of water, ft. per sec.
Added pressure, lbs. per sq. in.
Wall thickness, divided by inside diam.

FIG. 2

this dropping and its extent become difficult if not impossible to predict when the pipe has several sections of varying diameters and wall thicknesses. Where slow-moving regulating parts and safety devices are installed, the above conditions will not, of course, occur, except when derangement of the machinery eliminates the protection. The study of the worst possible conditions is of value in order to determine the kind and number of safety devices to be installed, and the amount of care in operation necessary to see that all are in good working condition.

The following explanation applies to Figs. 1 and 2. The lower row of figures represents the quotient obtained by dividing the thickness of pipe wall by the internal diameter. Starting at this figure, follow the vertical line to the proper curve for the pipe material, then horizontally to the line *A-B*, showing values of wave velocity in feet per second, then along the diagonal to the line *O-O*, horizontally to the diagonal representing the velocity of the water and vertically downward to the row of figures marked "added pressure." The result will be the ram pressure produced in that particular pipe by closing the gate within the time found by dividing twice the pipe length by the "velocity of wave." Should the gate be only partly closed, take the difference between the velocity before and after the movement instead of the total; it is the velocity lost which produces the ram. In Fig. 1, the dotted curves for cast iron and steel are extensions of the solid ones above, and when used, the lower scale must be read as though multiplied by 10, "added pressure," and all other figures are unchanged. They apply to pipes having ratios of wall thickness to inside diameter ranging from 0.03 to 0.36.

An inspection of the various curves will show that for a given diameter and thickness, steel gives the heaviest ram pressure, followed by cast iron, Douglas fir, and redwood. However, as cast iron is always used with heavy walls, it will be found in practice to exceed steel. Wood stave pipe gives low pressures but long periods of vibration. In these no account has been taken of the bands, as it is believed that the great difference in the elastic conditions will render the effects small.

Experiments prove that a pressure wave reflected from a dead-end becomes doubled in intensity unless some water is flowing

from it. With more than one unit taking water from a header, or from branches of a main line, simultaneous gate closure, or closure at intervals equal to four times the pipe length divided by the average velocity of wave, will produce pressures equal to the sum of the separate effects, while they will tend to equalize each other with movements at intervals equal to twice the pipe length divided by the average wave velocity. In the former case, dependence upon the safety appliance is much increased, and it becomes doubly important that the operator see that these are working properly. In all parts of a line, ram pressures should be kept low enough to prevent the following wave of subnormal pressure from reaching the vacuum limit, for in this case the water column will be broken and violent shocks set up, and the pipe be subject to a collapsing pressure.

The diagrams have been calculated for instantaneous closing of the gates, but, as stated previously, the pressure at the gate will be the same for any time of closing less than that required for the wave to make the trip to the reservoir and back. For a time of closing greater than this the pressure given should be multiplied by the round-trip time and the result divided by the closing time. The maximum pressure will reach the top of the line only when the gate is closed instantaneously, so there will be an advantage in slow closing even within the round-trip time.

For those who desire to study the derivation of the formulæ a list of references is given, which, while probably not complete, is extensive enough to cover the field satisfactorily. The most important and extensive work in this direction has been done by Joukowsky, who had unusual facilities in an experimental plant connected with the Moscow water works. The following are given by Church in his "Hydraulic Motors," while values for the modulus of elasticity of the various materials have been taken from several sources, those for Douglas fir and redwood from Circular No. 189, Forest Service, United States Department of Agriculture, 1912, averaged for green timber.

Let

E = bulk modulus of water, 300 000 lb. per sq. in.
E' = modulus of elasticity of the pipe material,
= 30 000 000 lb. sq. in. for steel,

$=16\,000\,000$ lb. sq. in. for cast iron for usual pressures,
$=1\,600\,000$ lb. sq. in. for Douglas fir (Oregon pine),
$=1{,}061\,000$ lb. sq. in. for redwood.
$E_2=E$ as modified by elasticity of pipe walls.
C =velocity of wave in water, pipe distention not considered.
C' =velocity of wave in water, pipe distention considered.
r =internal radius of pipe in inches.
g =386.4 in. sec.
γ =0.03604 lb. cu. in.
p =excess pressure in lb. per sq. in.
c =velocity of water (ft. per sec. or) in. per sec.
i =thickness of pipe wall in inches.
T =time of closing valve, sec.
T_r =time for round trip of wave to reservoir and back.
R_d =wall thickness divided by internal diameter.

When pipe distention is not considered,

(1) $$C=\sqrt{\frac{Eg}{\gamma}}=4726 \text{ ft. per sec.}$$

(2) $$p=c\sqrt{\frac{E\gamma}{g}}=63.3c \text{ (ft. per sec.).}$$

Considering the elasticity of the pipe-walls,

(3) $$C'=\sqrt{\frac{E_2g}{\gamma}} \text{ in which}$$

(4) $$E_2=\frac{EE't}{tE'+2rE} \text{ and the velocity of the wave.}$$

(5) $$C'=103.5\sqrt{E_2} \text{ in in. per sec. and}$$

(6) $$C'=8.625\sqrt{E_2} \text{ ft. per sec.}$$

(7) $$p=\frac{cC'\gamma}{g} \text{ in. sec. units.}$$

(8) $$=0.000093cC' \text{ in. sec. units.}$$

(9) $$=0.0134cC' \text{ for } c \text{ and } C' \text{ in ft. per sec.}$$

(10) When T is greater than T_r, pressure $p_1=\frac{pT_r}{T}$.

The following formulæ have been deduced from the curves of the diagrams which were constructed from the above. In the diagrams the ratios of wall thickness to internal diameter are given as being more convenient than ratios involving the radius. The values of E_2 may be found, if desired, as the curves are equilateral hyperbolas, with the ratios R_d for abscissæ and for ordinates the relation $\frac{E}{E_2}-1$ referred to the asymptotes. The constant K in the equation

$$R_d\left(\frac{E}{E_2}-1\right)=K$$

varies inversely as the modulus of elasticity of the pipe material and has a value of $\frac{300\,000}{E'}$, giving results as follows:

K for steel	$=0.01$
Cast iron	$=0.02$
Douglas fir	$=0.1875$
Redwood	$=0.2825$

From the above:

(11) $$E_2 = \frac{E}{\frac{K}{R_d}+1}.$$

For example, for steel pipe and $R_d = 0.008$,

$$E_2 = \frac{300\,000}{\frac{0.01}{0.008}+1} = \frac{300\,000}{2.25} = 133\,333 \text{ lb. sq. in.}$$

It will be noticed in the formulæ that the effect of pipe extension is treated as producing a virtual modification of the bulk modulus of water. The diagonals between the lines A-B and O-O are to permit the use of straight lines for water velocity. It follows also, from the formulæ given above, that the velocity of wave in a pipe of any material having a modulus of elasticity E',

$$C' = \frac{4726}{\sqrt{\frac{300\,000}{E'R_d}+1}}.$$

(12) $$C' = \frac{4726}{\sqrt{\frac{K}{R_d}+1}} \text{ in ft. per sec.}$$

By inserting the value of C' from (12) in (9) and reducing,

(13) $$p = c\left(\frac{63.3}{\sqrt{\frac{K}{R_d}+1}}\right)$$

with c expressed in ft. per sec. and p in lb. per sq. in.

From (11)

$$\frac{K}{R_d}+1 = \frac{E}{E_2}, \text{ therefore } p = c\left(\frac{63.3}{\sqrt{\frac{E}{E_2}}}\right).$$

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WATER RAM IN DISTRIBUTION SYSTEM, HARTFORD, CONN.

BY CALEB MILLS SAVILLE, CHIEF ENGINEER, HARTFORD WATER WORKS.

[*Read January 8, 1913.*]

The subject of Mr. Sherman's paper is of especial interest to me just at this time because the Water Department at Hartford also has been having recently some experience with water ram. A year ago this month the 30-in. supply main leading from the reservoirs to the city broke late in the evening of one of the coldest days of the year. One month later a similar misfortune happened to the 20-in. supply main in Asylum Street, and this year, only about a month ago, an 8-in. pipe in Church Street also broke. In casting about to explain these occurrences a very probable cause seemed to be the method of operating the standpipes for filling locomotives at the Union Station of the New York, New Haven & Hartford Railroad. While the break in the 30-in. main was located at a point about 1.5 miles distant from the Union Station, the Asylum and Church Street breaks were within a few hundred feet from the standpipes. As all of these mains let go immediately after the locomotive tanks had been filled, the occurrence of each break greatly strengthened the suspicion of the probable cause. As the result of the investigations, and after conference with the railroad people, it is probable that the trouble can be obviated in a manner satisfactory to all parties.

Several ways of handling this matter have suggested themselves: (1) By a slower motion valve on the standpipe. This is objected to by the railroad people on account of delay to train service. (2) The use of a water cushion valve on the standpipe which would act similar to the air checks on doors. This device is now in operation in various places and when new works very satisfactorily. After constant use, however, the parts wear and if repairs are not made the conditions of ram become as bad as before installation. (3) An air pressure tank or chamber may be

installed so devised that theoretically at least the shock of the quick closing valve will be mostly taken up by an air cushion. Such a device is in operation in several places, but it is understood to be not entirely satisfactory. This condition may be due, however, to a defect in installation rather than to anything inherent in the system. (4) An elevated and independent tank may be used, and this from a water-works standpoint is probably the most satisfactory solution of the problem. In this case the water may be drawn out as quickly as desired and the tank refilled by a steady stream that will be automatically and gradually cut off as the tank is filled. Unfortunately this method of solving the problem is not always feasible either on account of esthetic conditions which forbid an unsightly tank or on account of the cost of an architecturally satisfactory structure.

The diagrams presented are perhaps the best evidence needed to show the stress that is put on the pipes when quick motion valves are allowed on locomotive standpipes in cases where no effort is made to prevent ram.

Fig. 1 is from a recording pressure gage located on the 8-in. lateral directly supplying the standpipe. It is to be noted that the extreme vibrations of the pen show a total length representing about 120 lb. per sq. in.

Fig. 2 is from a recording pressure gage located in the Water Department office at City Hall about half a mile from the Union Station. This diagram is particularly interesting as showing that the water ram impulse is transmitted to considerable distance through a distribution system, and with a decidedly appreciable force. A few of the principal deflections have been marked here and there to identify the same period on these two charts. A number of observations during the period of filling the locomotive tanks have given the following information, which is believed to be fairly representative of the average conditions which obtain.

Capacity of locomotive tanks (through service)	6 000 to 7 000 gal.
Quantity usually drawn (meter readings)	4 230 gal.
Length of time flow is maintained	2 min. 50 sec.
Velocity in lateral	9.50 ft. per sec.
Size of lateral	8-in.
Size of street main	12-in. and 16-in.

Beside that from locomotive standpipes, another source of water ram may be found in the operation of steam fire engines. On December 13, at 2.15 A.M., an alarm was rung in for a fire in the building occupied by Smith & Northam on State Street, Hartford.

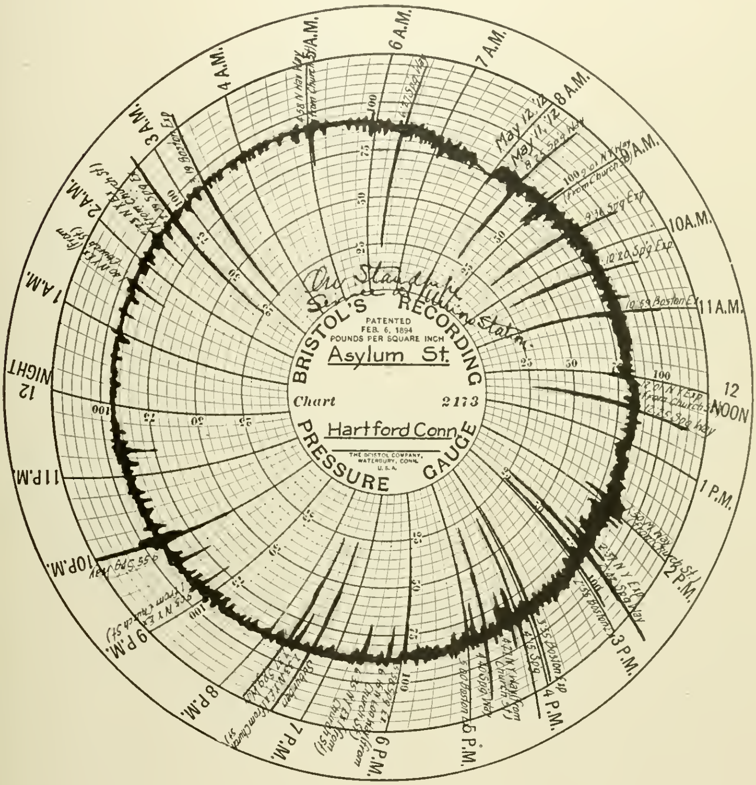

FIG. 1.

CHART FROM PRESSURE GAGE ON LINE SUPPLYING LOCOMOTIVE STANDPIPE.

The building was supposed to contain a considerable quantity of hay and was located in a district where serious results were apprehended if the fire was not quickly controlled. Besides other apparatus, four steamers responded. Two of them were of the

large self-propeller type, capable of delivering 1 200 gal. per min. each. The other two were of the ordinary type, one of 900 gal., the other of 600 gal., each per minute. Besides the above, the fire pumps at the nearby car barns of the Connecticut Company were

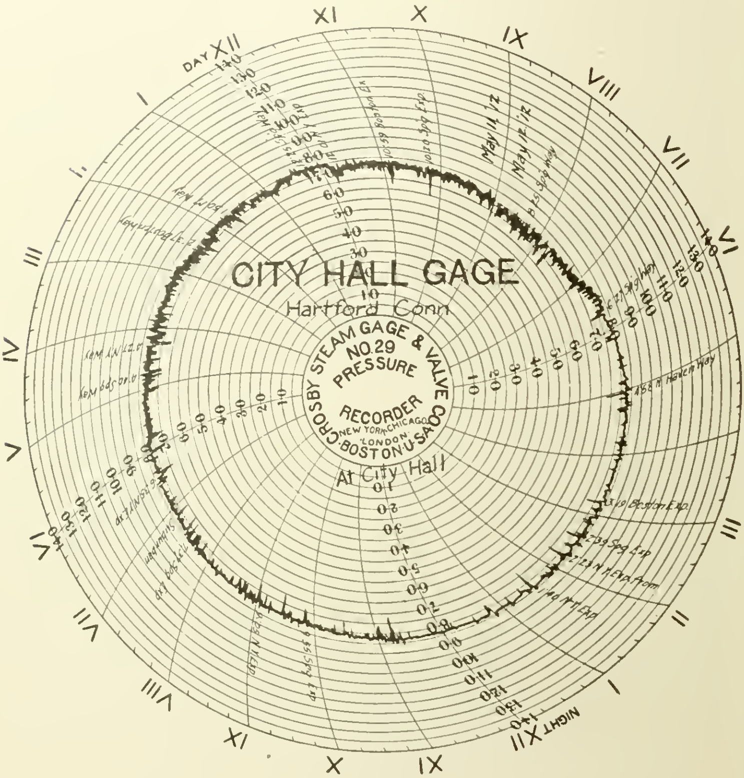

FIG. 2.

CHART FROM PRESSURE GAGE AT CITY HALL.

put in service. The hose line system consisted of the following lines: Two 3-in., four $2\frac{1}{2}$-in., and three $1\frac{1}{2}$-in. lines. The Venturi meter on the supply main at the effluent gate house indicated a draft for this fire of about 350 000 gal., the rates of draft in excess of the ordinary consumption being as follows:

Ten Minute Intervals.	Gallons per Hour.	Ten Minute Intervals.	Gallons per Hour.
1st period	125 000	9th period	110 000
2d	190 000	10th	130 000
3d	200 000	11th	140 000
4th	240 000	12th	100 000
5th	195 000	13th	70 000
6th	160 000	14th	30 000
7th	170 000	15th	20 000
8th	170 000	16th	30 000

Fig. 3 is from the recording pressure gage located in the Water Department office about 500 ft. from the location of the fire. The gage and the steamer were on the same main. Particular attention is called to the frequency of the vibration, which was such as to cause the pen to paint a continuous blotch rather than to show the individual movements. It is also to be noted that the extreme length of vibration corresponds to about 110 lb. pressure per sq. in. The withdrawal of some of the fire engines is well marked, especially at about 3.30 A.M., by the sudden cessation of the extreme amplitude of vibration.

In connection with this diagram it may be of interest to state that the city of Hartford has recently passed through a rather disturbing period due to low rainfall and the excessive calls that have been made on the storage in the reservoirs. In order to take every precaution possible to conserve the supply and to put off as long as possible the evil day of turning to the Connecticut River for an emergency supply, the gates on the supply mains were throttled down during the late afternoon and night. The intention was to keep the pressure during this period at about the same point as it stood during the day hours of maximum consumption. A drop in pressure of about 15 lb. per sq. in. was made in this manner, and the Venturi meter records indicate a saving of at least a quarter of a million gallons per day. By good fortune there are two fire engine houses not far from the city line and also near the main gates on the supply main. Two men were stationed at each of these houses, and on an alarm of fire they open the gates

as soon as possible. A number of alarms have come in during this period, but at no time has there been any lack of pressure when the engines arrived. The ordinary night consumption at this season of the year is at a rate of about 4 000 000 gal. per day.

FIG. 3.

VARIATION IN PRESSURE CAUSED BY FIRE ENGINES.

The time of closing the gates appears on the diagram about 3 P.M., and the effect of opening up on account of other fire alarms the same night is shown at 8 P.M., 12.45 A.M. and 2.15 A.M. Ordinarily the gates are opened each morning at 5.30 A.M.

DISCUSSION.

Mr. G. A. Caldwell. Has anybody here ever used a reducing valve to obviate water hammer, especially in connection with filling locomotive engine tanks?

Mr. Saville. I haven't had any. I should like to get some information on that subject.

Mr. Caldwell. I think if you would test that out it would help to you overcome your difficulty. The principle of a regulator is that by reducing the size of the opening it increases the velocity of the water passing through the smaller opening. When you close your valve on the outlet end, you have a back pressure which closes off your regulator, and, therefore, you will not get the hammer back of the regulator, — that is, I do not think you will. At all events, I believe a test along those lines would be worth while, and I think the result would be satisfactory and would save you some money.

Mr. Saville. I am certainly glad to get the suggestion.

Mr. F. W. Dean.* It seems to me that using a reducing valve would be equivalent to using a slow moving valve, which the railroad company in the case mentioned objected to.

I have experimented on a small scale recently at my house by connecting a refined test gage permanently in my bath room to the water pipe, and it is very interesting to see how it behaves. When the flush valve of the water closet is opened, the pressure immediately drops from 73 lb. to 20 lb. Of course if it went back quickly it would make a severe water hammer, but as these flush valves close by the rising of a ball float, the action is slow and nothing happens. It is interesting to observe how water impulses travel apparently all over the town. The hand of this gage is never still, but is constantly varying from 1 to 3 lb.

Undoubtedly the best method of suppplying the service required by railroads would be to have a float valve which would deliver water into a tank. The locomotive would get the water quickly from the tank, but the float valve would close so slowly that there would be no water hammer.

* Mill Engineer and Architect, Boston, Mass.

Mr. John Doyle.* I should like to ask Mr. Saville at what elevation above the city proper the break in the 30-in. force main of which he spoke occurred?

Mr. Saville. I think it was an elevation of about 40 or 50 ft.

Mr. Doyle. Was it anywhere near the reservoir?

Mr. Saville. No; it was five miles from the reservoir.

Mr. Doyle. We had some trouble in Worcester on a 40-in. main, but it was near a regulating valve, and the trouble occurred after there had been several large fires. We had, I think, two or three breaks on the 40-in. main. Those breaks were caused in my opinion by water hammer, as the pipe burst right through the center of the bottom in all cases. Through the orders of Mr. Batchelder, the commissioner, we put on three 2½-in. Ross relief valves and connected them together, and we haven't had any trouble at this point since. It has done away with the hammer. I have recently taken some observations there, have had a gage put on at this particular place, and everything is working first rate. The last time this 40-in. main broke was nearly a quarter of a mile away from where our regulating valves are located, down on the main thoroughfare, but the conditions were the same as they were at the time of the break up nearer the regulating valves. The pipe burst right through the center from bell to spigot. After taking the pipe out I noticed that it was comparatively dry at the top, two thirds of the upper part of it, showing that the water hadn't reached it for some time.

Mr. Allen Hazen.† This question of railroad supplies is a very important one, and one that gives much trouble in many works. I have been advising some of my clients not to permit direct pipe connections to feed locomotives, but have advised that such supplies be furnished only through tanks. This may be an expensive method, but it is a sure one. If there is an easier and simpler way of performing the service without danger of water ram, we should all be glad to know of it. Perhaps the incoming administration will take up this subject and see if a standard procedure can be adopted, and if it can be, it will add to the many good works that the Association already has to its credit.

* General Foreman, Water Department, Worcester, Mass.

† Civil Engineer, New York City.

I believe it to be a fact that the tighter the pipe system is made, the more water hammer is experienced. Where pipe systems are very tight and all the services are metered, and leaks have been thoroughly and systematically stopped, it is necessary to be very careful about quick closing valves, or anything else tending to make water hammer, but in pipe systems that are leaky and where the services are not metered, every leak and every service is a relief valve, and there is not much water hammer.

Now water is getting to be better and more valuable, and it is worth while to take more care to prevent it from wasting. Pipe systems of the future are going to be tight, and the matter of water hammer will be even more important than it has been.

At Des Moines, Ia., where the pipe system is very tight and where water hammer had been bothersome, a large steel tank, corresponding to a boiler, was connected with the pipes near the pumping station, which is quite near to the business center of the city, and this tank was kept full or partly full of air by an air pump. It was found that this tank steadied the service in a satisfactory way.

It may be that devices of this kind may prove advantageous, but in the meantime, quick closing valves are to be discouraged on all pipes connected with a system.

Mr. Charles E. Peirce.* Mr. Chairman, speaking of a steel air tank, I would say that one has been installed in the works which I represent, and it certainly has helped to relieve the water hammer, although it has not been entirely satisfactory. The tank is quite a large one, about 10 ft. high by 6 ft. wide. We have a pretty high pressure. The highest pressure when the standpipe is full is about 150 lb. at sea level. We carry from 130 to 140 lb. We have elevators from which we get some trouble. We used to get it at the station on our steam pump more particularly, but we have not used the pump during the last year to any great extent, as we have installed electric service there.

Mr. John Doyle. I would suggest that a good way to avoid trouble in the down-town district is to put in heavy pipes and do first-class work. In my opinion that will obviate any trouble. We never have had any trouble in Worcester from the elevators.

* Superintendent East Providence Water Company, Rumford, R. I.

We have something like 300 elevators and carry a direct pressure on our high service system. At City Hall we have a pressure of 140 lb. to the square inch, and we have never had any trouble at all with water hammer on our main system through the city, nor on any of our elevator pipes.

MR. F. L. FULLER.* The system at Winchendon, Mass., was supplied with relief valves when the works were built. I cannot give any information as to how they have worked. They were installed in 1892.

MR. E. S. TUCKER (*by letter*).† Our system is equipped with relief valves. We have not paid much attention to them and we are not troubled with water hammer.

MR. JOHN C. WHITING (*by letter*).‡ There is not a relief valve in the Newton system, though at one time we seriously considered putting them on two lines from which locomotive standpipes drew their supply and from which considerable trouble was experienced from water hammer. We found the trouble was caused largely by the rapidity with which these standpipe gates were opened and closed, and as a very coarse thread was used on the spindle, it took comparatively few turns to fully open or close.

The case was presented to the Railroad Company with request that gates having a finer thread be substituted; since installing them practically no trouble has been caused by the standpipes.

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* Civil Engineer, Boston, Mass.
† Water Commissioner, Winchendon, Mass.
‡ Water Commissioner, Newton, Mass.

DECARBONATION AS A MEANS OF REMOVING THE CORROSIVE PROPERTIES OF PUBLIC WATER SUPPLIES.

BY GEORGE C. WHIPPLE, OF HAZEN & WHIPPLE, CONSULTING ENGINEERS, NEW YORK CITY; PROFESSOR OF SANITARY ENGINEERING IN HARVARD UNIVERSITY.

[*Read March 12, 1913.*]

Almost all natural waters used for public water supply are corrosive of the pipes through which they flow and the metal structures with which they come in contact. Various causes contribute to this corrosive property, but, omitting those of minor importance or of significace in special cases only, the three primary factors that water-works engineers need to consider are carbonic acid, oxygen, and the pipes themselves.

Thus far the last of these has received most attention. Much care has been taken in the choice of metals used, in the quality of the metals selected, and in the protective coating employed. Many questions as to the relative value of wrought iron and steel, the use of protective metals such as tin and zinc, the use of asphalt, coal tar, cement, and other coatings, have been actively discussed by this Association on previous occasions. Comparatively little attention has been given to measures for removing the corrosive properties of the water itself, that is, for getting rid of the carbonic acid and dissolved oxygen, although both measures have been practiced to some extent in different parts of the world. Thus, at Coolgardie, in Australia, it has been suggested that the oxygen be removed from the water by a vacuum process in order to reduce the corrosion in the long steel pipe line. The removal of oxygen from hot water by exposure to the air has been suggested and used with some success in preventing the corrosion of hot water pipes. Carbonic acid is removed from certain ground-waters in Germany and elsewhere by aëration as an incident to the iron removal process, while in England it is neutralized by the use of chalk.

Reduction of the corrosive properties of water by oxygen removal is a very difficult matter and could not be applied to a public water supply without great expense. It would also be

undesirable and need not be considered further. The decarbonation of water, that is, the removal or neutralization of the carbonic acid gas, is a much simpler matter and one that can be accomplished practically. It is the removal of the corrosive properties of water by decarbonation that forms the subject of the present paper. The methods discussed are aëration and the use of soda and lime. The latter is so intimately connected with the hardness of water that this important subject may be logically considered first.

Softness of New England Waters.

Most of the water supplies of New England are extremely soft. The Massachusetts State Board of Health, in its annual report for 1909, gave the hardness of 153 surface waters and 90 ground waters used for public water supplies in the state. These may be grouped as follows:

TABLE 1.

The Hardness of Certain Massachusetts Water Supplies.
(Mass. State Board of Health, 1909).

Hardness, Parts per Million.	Number of Supplies where the Average Hardness was between the Figures Indicated.			Per Cent. of Supplies where the Average Hardness was between the Figures Indicated.		
	Surface Waters.	Ground Waters.	Total.	Surface Waters.	Ground Waters.	Total.
0 to 5	30	5	35	19.6	5.5	14.4
6 to 10	40	9	49	26.2	10.1	20.2
11 to 15	29	10	39	19.0	11.0	16.1
16 to 20	18	15	33	11.8	16.6	13.6
21 to 30	19	20	39	12.4	22.3	16.1
31 to 40	9	11	20	5.9	12.3	8.2
41 to 50	2	11	13	1.3	12.3	5.3
51 to 60	3	5	8	2.0	5.5	3.3
61 to 70	1	1	2	0.6	1.1	0.8
71 to 80	1	1	2	0.6	1.1	0.8
81 to 90	0	0	0	0.0	0.0	0.0
91 to 100	1	1	2	0.6	1.1	0.8
101 or over	...	1	1	....	1.1	0.4
Total,	153	90	243	100.0	100.0	100.0

It will be seen from these figures that half of the surface waters are softer than 10 parts per million, and three quarters of them are softer than 20 parts per million. In only 5 per cent. of the surface supplies does the hardness exceed 50 parts per million. The ground water supplies are slightly harder, but they also are, on the whole, very soft. Half of them are softer than 25, and nearly nine tenths of them are softer than 50 parts per million. The hardest waters are found in Berkshire County, in the western part of the state, where limestone exists. A few supplies near the seacoast are doubtless influenced to some slight extent by the sea water.

The large cities of the state are all supplied with very soft water, as the following figures show:

TABLE 2.

Hardness of the Water Used by the Cities of Massachusetts which had Populations of More than 25 000 in 1910.

City.	Population.	Hardness. Parts per Million.
Boston, Metropolitan District,	1 046 630*	12
Worcester,	145 986	11
Fall River,	119 295	7
Lowell,	106 294	19
Cambridge,	104 839	29
New Bedford,	96 652	7
Lynn,	89 336	15
Springfield,	88 926	12
Lawrence,	85 892	14
Holyoke,	57 730	20
Brockton,	56 878	5
Haverhill,	44 115	18
Salem,	43 697	20
Newton,	39 806	28
Fitchburg,	37 826	5
Taunton,	34 259	5
Waltham,	27 834	38
Gloucester,	24 398	4

The water supplied to the Metropolitan District of Boston, with a population of over a million people, has a hardness that averages about 12 parts per million; the supply of Worcester, the next

*Estimate for 1911.

TABLE 3.

HARDNESS OF THE WATER SUPPLIES OF LARGE AMERICAN CITIES.

The following figures represent the approximate average hardness for the year, in parts per million, based on the best available analyses. In some cases the seasonal variations from the average hardness are very great.

[ ] = raw water.

City.	Population, 1910.	Water Supply.	Hardness. Alkalinity.	Hardness. Incrustants.	Hardness. Total Hardness.	Year.	References and Remarks.
New York:	4 766 883	Esopus Creek.	16	4	20	1903	New supply. Not yet used.
Manhattan...		Croton River.	36	2	38	1907	Ann. Rep., Dept. W. S., G. & E.
Bronx........		Bronx River.	27	5	32	1907	Ann. Rep., Dept. W. S., G. & E.
Brooklyn.....		Ridgewood, wells and streams.	16	16	32	1907	Ann. Rep., Dept. W. S., G. & E.
Queens.......		Chiefly wells.	11 to 183	1 to 171	12 to 354	1907	Some of the wells are affected by sea-water.
Richmond....		Chiefly wells.	76 to 143	33 to 101	144 to 179	1903	
Chicago........	2 185 283	Lake Michigan.	116 to 124				L. M. Water Com.
Philadelphia....	1 549 008	Delaware River.	24	19	43	1900	G. C. W.
		Schuylkill Rriver.	41	47	88	1911	
St. Louis.......	687 029	Mississippi River.	[135]−50	[24]−41	[159]−91	1908	Wall: Am. Soc. C. E., Vol. LX, p. 187.
Boston.........	670 585	Sudbury and Nashua Rivers.	10*	2*	12	1909	Mass. State Bd. Health.
Cleveland......	560 663	Lake Erie.	85	7	92	1912	Jackson's Rep., p. 116.
Baltimore......	558 485	Jones Falls Creek	70	−4	66	1910	June only.
		Gunpowder Creek.	45	−5	40		
Pittsburgh......	533 905	Allegheny River.	25	25	50	1910	Annual Report.
Detroit........	465 766	Detroit River.	85	4	89	1909	Dole: W. S. & I. P. No. 236, p. 126.
Buffalo.........	423 715	Niagara River.	98	11	109	1909	Dole: W. S. & I. P. No. 236, p. 116.

San Francisco...	416 912	Surface and ground water.			100	1911	Allen Hazen.
Milwaukee.....	373 857	Lake Michigan.	108	7	115	1910	Sewerage Commission.
Cincinnati......	364 463	Ohio River.	[40]−45	38−46	[78]−91	1911	Ann. Rep., Water Dept.
Newark........	347 469	Pequannock River.	15			1911	State Bd. Health.
New Orleans....	339 077	Mississippi River.	[92]−38	[22]−24	[114]−62	1909	Earl.
Washington.....	331 069	Potomac River.	30	49	79	1909	
Los Angeles.....	319 198	Los Angeles River.	200	61	261†	1908	
Minneapolis....	301 408	Mississippi River.	154	4	158	1909	Dole: W. S. & I. P. No. 236.
Jersey City.....	267 779	Rockaway River.	35	7	42	1911	
Kansas City....	248 381	Missouri River.	166	64	230		
Seattle.........	237 194	Cedar River.			14	1913	Jacobsen.
Indianapolis....	233 650	White River.	240	5	249	1909	Dole.
Providence.....	224 326	Pawtuxet River.	10	10	13	1912	State Bd. Health.
Louisville.......	223 928	Ohio River.	[66]−53	29−38	[95]−91	1911	Ann. Rep., Water Dept.
Rochester......	218 149	Hemlock Lake.	65	6	71	1912	City Chemist.
St. Paul........	214 744	Natural lakes.					
Denver........	213 381	Impounding reservoir.	95	70	165		
Portland, Ore....	207 214	Impounding reservoir.					
Columbus......	181 548	Scioto River.	[151]−40	[102]−53	[253]−93	1909	Ann. Rep., Water Dept.
Toledo.........	168 497	Maumee River.	[145]−119	[76]−105	[221]−224		
Atlanta........	154 839	Chattahoochee River.	9				
Oakland........	150 174		165	15	180	1910	
Worcester......	145 986	Impounding reservoir.			11		
Syracuse.......	137 249	Skaneateles River.			98		
New Haven.....	133 605	Lake Whitney			33	1901	State Bd. Health, 1901, p. 329.
		Dawson Lake.			15		

* Estimated.

† New supply from Owens River has hardness of 158.

TABLE 3.—*Continued.*

City.	Population, 1910.	Water Supply.	Hardness. Alkalinity.	Hardness. Incrustants.	Hardness. Total Hardness.	Year.	References and Remarks.
Birmingham....	132 685	Cahaba River.					
Scranton.......	129 861	Impounding reservoir.					
Richmond......	127 628	James River.	[39]—36				
Paterson.......	125 600	Passaic River.	25	20	45		
Omaha.........	124 096	Missouri River.					
Fall River......	119 295	Watuppa Lake.			7		
Dayton........	116 577	Wells.	275	15	290	1904	State Bd. Health
			[200]	[60]	[260]	1911	
Grand Rapids...	112 571	Grand River.	190–225	50–85	240–280		*Engineering Record*, Vol. 64.
Nashville.......	110 364	Cumberland River.					
Lowell.........	106 294	Driven wells.			19		
Cambridge.....	104 839	Stony Brook.			29		
Spokane........	104 402		130	24	154		Pegg.
Bridgeport......	102 054	Impounding reservoir.			8		State Bd. Health, 1896, p. 295.
Albany.........	100 253	Hudson River.	40	32	72	1912	Geo. E. Willcomb.

largest city, has a hardness of only 11 parts per million; and Fall River, the third city, 7 parts per million. The Lowell water supply, taken from driven wells, has a hardness of 19, and the Cambridge water supply, with its reservoirs quite near the city, shows a hardness of 21 parts per million in its main reservoirs, which increases to 29 as it passes through Fresh Pond.

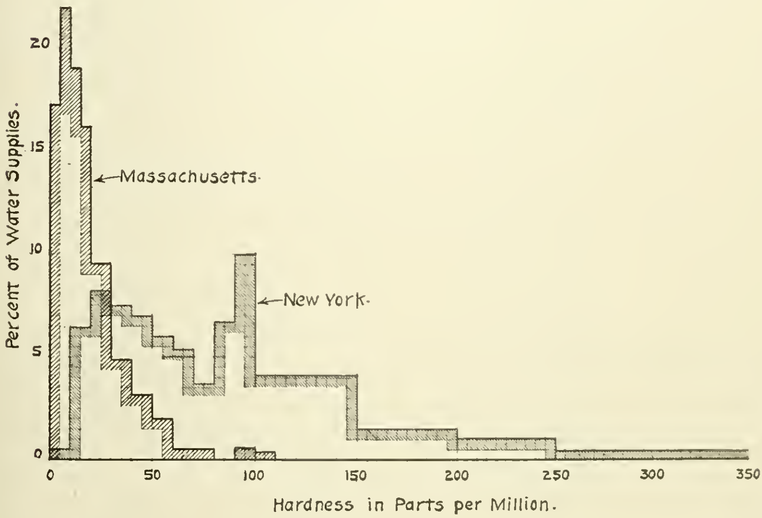

Fig. 1.

Classification of the Public Water Supplies of Massachusetts and New York, according to Hardness.

For comparison with these figures the hardness of the water supplies of some of the largest cities of the country is given in Table 3. It will be seen that no large city in the country has a water supply that approaches in softness that of the Metropolitan District of Boston. The hardness of the water supplies of New York State is shown in Table 4.

TABLE 4.

CLASSIFICATION OF THE PUBLIC WATER SUPPLIES OF NEW YORK STATE ACCORDING TO HARDNESS.

(From analyses published in the Annual Report of the State Department of Health for 1910, page 280.)

Hardness, Parts per Million.	Number of Supplies where Hardness was between the Figures Indicated.	Per Cent. of Supplies where the Hardness was between the Figures Indicated.
0 to 10	1	0.3
10 to 20	19	6.3
20 to 30	25	8.2
30 to 40	22	7.3
40 to 50	21	6.9
50 to 60	18	5.9
60 to 70	16	5.3
70 to 80	11	3.6
80 to 90	20	6.7
90 to 100	30	9.9
100 to 150	61	20.2
150 to 200	22	7.3
200 to 250	17	5.6
250 to 300	5	1.6
300 to 400	5	1.6
400 to 500	4	1.3
500 to 600	4	1.3
600 to 700	0	0.0
700 to 800	2	0.7
Total,	303	100.0

ADVANTAGES OF SOFT WATER.

Soft waters have a more agreeable feel to the skin when used for bathing, and are less likely to cause the hands to chap. They do not curdle with soap, and deposits of calcium soaps do not form in the pores of the skin. They readily form suds. Soft waters have a greater cleansing power both for the skin and for fabrics.

Hard waters require larger amounts of soap to produce suds, and the soap consumption increases quite regularly with the hardness of the water. It has been calculated that the increased cost of soap used by a community amounts to 10 cents per million gallons of water for each part per million of hardness. This is based on a

water consumption of 100 gal. per capita daily, and assumes that only one gallon per day is completely softened with soap, the cost of soap being taken at 5 cents per pound. For example, the water of New York City, with a hardness of 35 parts per million, imposes on the water consumer a cost of $2.30 per million gallons more than the water of Boston, with a hardness of 12 parts per million. One of the advantages of the new supply of New York City, that is to be derived from the Catskills, will be its lower hardness than that of the present Croton supply.

Hard waters are also objectionable for various industrial uses and steam production. Soft waters are said to be more satisfactory than hard waters for cooking vegetables, for making tea, and other household operations.

These are all matters that are well known to water-works engineers, and do not need to be elaborated.

Disadvantages of Very Soft Water.

The disadvantages of very soft waters relate to the effect that they have on the pipes through which they are distributed. This brings in two very different problems, both of considerable importance, namely, lead poisoning, and the red water plague.

Lead Poisoning.

Not much has been heard lately in regard to lead poisoning caused by public water supplies. In years past it was a serious problem in many places, and within ten years the annual reports of the Massachusetts State Board of Health contain numerous references to the subject, notably in connection with the water supplies of Lowell, Milford, Hopedale, Milton, Gilbertsville, Norwood, Fairhaven, New Bedford, and Kingston. Three important reports are worth noting, namely:

"An Investigation of the Action of Water upon Lead, Tin, and Zinc, with Special Reference to the Use of Lead Pipes with Massachusetts Water Supplies." By H. W. Clark. (Annual Report, 1898, page 541.)

Report of Dr. F. L. Morse on Lead Poisoning. (Annual Report, 1899, page 31.)

"Continuation of an Investigation of the Action of Water upon

Metallic or Metal Lined Service Pipes." By H. W. Clark and F. B. Forbes. (Annual Report, 1900, page 487.)

These investigations showed that the primary active agent in causing water to attack lead pipe was dissolved carbonic acid gas, dissolved oxygen being an important contributory factor. Certain chemical constituents, such as lime, exerted a deterrent influence, especially those which tended to cause a protective coating to form on the pipe. In no case was a large amount of lead found in water that had a hardness of more than 50 parts per million, and very seldom when the hardness was more than 25 parts per million. While it may be fairly said that hard waters protect against lead poisoning, it is not fair to infer that soft waters necessarily attack lead pipes and cause poisoning, for not all soft waters contain large amounts of carbonic acid. Of two waters, one hard and one soft, which contain the same amount of dissolved carbonic acid, the soft water would probably have the greater action on lead pipes.

Generally speaking, dissolved carbonic acid is higher in ground waters than in surface waters, but in swampy or peaty waters that are more or less stagnant, where bacterial action is vigorous, it may be relatively high. Such waters in New England are apt to be soft, hence the soft waters are often associated with lead poisoning.

In middle England, where many of the cities are supplied from so-called "moorland" sources, there were repeated recurrences of lead poisoning, and at one time the issue was a vital one. Some of the most valuable writings on the subject date from that time, and lead poisoning is given prominence in most English text-books on water supplies.

It is interesting to note that the problem of lead poisoning has been solved in two different ways, — in New England by abandoning the use of lead, and in England by removing the carbonic acid from the water.

Abandonment of Lead Pipe in Massachusetts.

Early in the history of American water supplies, when the use of hot water became general, practice set against the use of lead pipe for carrying hot water, brass being substituted.

The State Board of Health of Massachusetts has consistently advised against the use of lead pipe for house service connections in places where the water was found to act on this metal, and has recommended cement-lined pipe or tin-lined lead pipe having a thick layer of tin. Wrought-iron and steel pipes, generally galvanized, have been also used, but waters that will corrode lead will also cause these pipes to rust.

The annual report of the Massachusetts State Board of Health for 1905 (page 197) gave a list of the materials used for service pipes in the cities of the state, and from the data there given the following table has been made, the different water supplies being classified according to hardness from data given elsewhere in the report:

TABLE 5.

SERVICE PIPES USED IN MASSACHUSETTS CITIES CLASSIFIED ACCORDING TO THE HARDNESS OF THE WATER.

(Compiled for the Annual Report of the Massachusetts State Board of Health, 1905, page 197.)

Hardness, Parts per Million.	Number of Cities Using Chiefly the Service Pipes Indicated.				
	Lead or Lead-Lined Pipes.	Tin-Lined Pipes.	Cement-Lined Pipes.	Galvanized Iron (or Steel) Pipes.	Total.
Surface Water Supplies.					
0 to 10	9	2	14	19	40
11 to 20	9	0	3	9	21
21 to 100	0	1	0	10	11
Ground Water Supplies.					
0 to 10	1	0	5	1	7
11 to 20	2	2	7	5	16
21 to 50	4	1	10	14	29
51 to 100	0	0	1	5	6
					130

TABLE 5. — *Continued.*

Hardness, Parts per Million.	Per Cent. of Cities Using Chiefly the Service Pipes Indicated. Lead or Lead-Lined Pipes.	Tin-Lined Pipes.	Cement-Lined Pipes.	Galvanized Iron (or Steel) Pipes.	Total.
			Surface Waters.		
0 to 10	20	5	32	43	100
11 to 20	43	0	14	43	100
21 to 100	0	0	9	91	100
			Ground Water.		
0 to 10	14	0	72	14	100
11 to 20	12	12	44	32	100
21 to 50	14	3	35	48	100
51 to 100	0	0	16	84	100

It will be seen that the use of galvanized iron and steel pipe is favored for hard waters. This is natural, as hard waters do not cause iron to rust as soft waters do, and where usable, iron or steel are preferred on account of cheapness.

Lead pipe is used in 18 cities where soft surface waters are used (hardness less than 20 parts per million), but 47 cities use something else. Three cities supplied with soft ground water (hardness less than 20 parts per million) use lead service pipes, but 20 cities use something else. In round numbers, less than one quarter of the cities supplied with soft water are provided chiefly with lead services.

Tin-lined pipe and cement-lined pipe are used chiefly in the cities supplied with soft water. This is emphatically true of cities supplied with surface waters. Cement-lined pipe is also much used in cities supplied with moderately hard water, doubtless because the waters contain considerable carbonic acid.

Thus experience has taught the water-works superintendent to avoid the use of lead, iron, and steel for soft water because of corrosion, to use iron or steel for waters that are quite hard for reasons of economy, and to use cement-lined or tin-lined pipe for soft waters and waters of moderate hardness that contain carbonic acid. The theory of corrosion would have led to the same choice.

Water Hardening in England.

For many years the practice of hardening the very soft water supplies of middle England has been common. This is done by adding powdered chalk, or calcium carbonate, which unites with the dissolved free carbonic acid to form calcium bicarbonate, which is soluble.

At Sheffield, where an investigation of the prevalence of lead poisoning was made, it was recommended:

"That by way of practical experiment, a small but sufficient quantity of chalk in a minute state of division, which would not prejudicially affect the water for domestic or manufacturing purposes, be added to the water before its distribution to the town."

At a later date, after the method had been tried, it was recommended:

"That this process for treating the water with carbonate of lime in the form of chalk, or such modification as experience may show to be an improvement, be permanently continued, and that such apparatus be provided and fitted up as will permit the addition of the material to the water in an automatic manner which should be regular and continuous."

The process has been carried on as follows: *

"A measured quantity of levigated chalk, known commercially as Paris white, is placed twice a day in a small tank, oblong in plan and triangular in elevation, filled with water. A small revolving fan keeps the milky mixture continuously stirred, while a series of dredger buckets, on a chain revolving through the liquid, empties it in small constant quantities into a tank, where it is kept in motion by rotating plates. It is further diluted by a constant stream of water and discharged through a pipe below the gage basin into the main supply. The whole of the machinery is worked by a small, triple-ram water motor, the water from which is discharged into the gage basin. The weight of chalk is so regulated as to add a definite quantity varying from about 15 to 30 parts per million, according to the state of the water and its capacity for dissolving the carbonate of lime. The process is applied to the whole supply. The cost is about 52 cents per million gallons. No complaints of plumbo-solvent action have been received since its adoption."

* Notes on the Sheffield Water Supply. By L. S. M. Marsh. Proc. Inst. C. E., Vol. CLXXXI, Session 1909-10.

This method, first used in Sheffield, has been adopted in other places.

At Birmingham, where the water supply, taken from the Elan and Claerwen rivers in Wales, has a slight action on lead, Dr. Percy Frankland, F.R.S., recommended the addition of chalk to the water of the aqueduct after filtration. The works for carrying out this recommendation were designed and carried out by Mr. McCaulay,* as follows:

"A chalk-store, holding about 200 tons of chalk in bags, was erected near the west end of the filter beds, and from it chalk is carried by overhead conveyors along the filter beds to the chalking-house at their east end. There it is lifted into a hopper on the upper floor, which has a capacity sufficient for three or four days' chalking. From this hopper it is carried over a weighing machine to shutes above the four mixers already installed, two being at present in use at a time. These mixers are of the same design as those used at Sheffield except that they are without the second mixing tank."

The annual reports of Dr. J. F. Liversiege, the public analyst of the city, for the years 1905 to 1907, state that the addition of the chalk raises the hardness about 10 parts per million, the amount used being a little less than one grain per gallon. The hardness of the water as delivered to the city varies from 25 to 35 parts per million.

In 1905 Dr. Raymond Ross, of Burnlay, informed the author that chalk was added to the supply of that city to neutralize the effects of the humic acid. The hardness of the water was about 20 parts per million.

Theoretical Considerations.

There are several forms in which lime and carbonic acid may be present in water and in the air, and to avoid misunderstanding, these are briefly described.

1. Quick lime, known chemically as calcium oxide, or CaO. Placed in water, it immediately combines with it.

2. Water-slaked lime, or calcium hydrate, CaO_2H_2, or $CaO.\ H_2O$. This is soluble in water to the extent of 1 400 parts per million

* Proc. Inst. C. E., Vol. CLXXXI, p. 8.

(in terms of CaO) at 0° C.; 1 330 at 10°; 1 250 at 20°; 1 200 at 25°; 1 160 at 30°; 970 at 50°; and 580 at 100° C.

3. Calcium carbonate, or chalk or marble, known chemically as the normal carbonate, or $CaCO_3$, or $CaO. CO_2$. It is produced by the combination of CO_2 and CaO. Air slaked lime is partly this compound, as the CO_2 of the air unites with some of the CaO. The normal calcium carbonate is only slightly soluble in water, its solubility being only about 12 parts per million. The CO_2 in this combination is said to be "full bound."

4. Calcium bicarbonate, or $CaCO_3. H_2CO_3$, the ordinary form found in water. It is very soluble. It is also easily decomposed. The CO_2 can be driven off by heat, leaving the normal carbonate which will precipitate if present in amounts larger than about 13 parts per million.* Certain algæ can seize the CO_2 from the bicarbonate form and leave $CaCO_3$, which will precipitate. In this way certain marls are formed at the bottom of ponds. The CO_2 in this form is said to be "half-bound."

5. Carbonic acid is a gas and will dissolve readily in water. The amount that will remain in solution depends upon the partial pressure of CO_2 in the atmosphere over the water. (See Table 6.) In the open air this partial pressure is low, and water exposed to the open air in drops seldom contains more than 1 or 2 parts per million of free CO_2. The air in dug wells often contains a good deal of carbonic acid, so that ground waters often hold very large amounts of this gas. Animal organisms exhale it and bacteria produce it from organic matter, so that stagnant or polluted surface waters may contain relatively large amounts.

Carbonic acid has a natural affinity for calcium carbonate and in water will combine with it to form the soluble bicarbonate. In fact, waters become hard only as this action takes place, both limestone and the dissolved gas being necessary.

But carbonic acid has a stronger affinity for calcium oxide than for calcium carbonate, so that if the oxide or hydrate is added to water that contains calcium bicarbonate it will seize the extra molecule of carbonic acid, and the normal carbonate will be formed by

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* The Solubility of Calcium Carbonate and of Magnesium Hydroxide and the Precipitation of these Salts with Lime Water. By G. C. Whipple and Andrew J. Mayer. Journal of Infectious Diseases, Supplement No. 2, February, 1906, p. 151.

the combination, leaving another molecule of normal carbonate unattached to CO_2, so that a double precipitation will occur. This is the basis of the well-known Clark process of water softening.

The English method of adding chalk to water neutralizes the free CO_2 and yields $CaCO_3 \cdot H_2CO_3$, which remains in solution.

TABLE 6.

SOLUBILITY OF CARBONIC ACID IN WATER.

(Compiled from Sutton's Volumetric Analysis and Fox's paper in the Transactions of the Faraday Society, September, 1909.)

Temperature, Centigrade.	CC. per Liter.* 1 part per 10 000.	Parts per Million for Stated Partial Pressures of CO_2 in the Atmosphere.			
		1 part per 10 000.	4 parts per 10 000.	6 parts per 10 000.	8 parts per 10 000.
0	.1713	.34	1.4	2.0	2.8
4	.1473	.29	1.2	1.7	2.4
8	.1283	.26	1.0	1.5	2.0
12	.1117	.22	.9	1.3	1.8
16	.0987	.19	.8	1.2	1.6
20	.0877	.17	.7	1.0	2.0
24	.0780	.15	.6	.9	1.8
28	.0780	.15	.6	.9	1.8

Substantially the same result would be reached by adding lime, but chalk in England occurs as a natural deposit and is cheaper than lime. In New England, lime would be naturally used instead of chalk for reasons of economy.

There would be this difference, however, that if an excess of lime were used, the Clark reaction would occur, that is, the end produced would be not all bicarbonate, but partly normal carbonate, and if this amounted to more than 13 parts per million, a precipitation of sludge might occur and cause trouble, just as it does in St. Louis and Columbus and elsewhere where water is softened. In what follows it is assumed that the addition of lime is only sufficient to combine with the carbonic acid present and not enough to attack the bicarbonates.

* 1 cc. of CO_2 at 0° C. and 760 mm. weighs 1.96663 mg.

Advantages and Disadvantages of Lime Treatment.

The question has arisen in the minds of some as to whether it would not be of advantage to follow the English practice and neutralize the humic acid and the free carbonic acid of the very soft waters of New England. To do so would slightly increase the hardness but would prevent danger from lead poisoning, and would make it possible to use pipes of wrought iron or steel in places where the more expensive tin-lined or cement-lined pipes are now employed. This question is not as simple as it might appear at first thought. It involves a considerati n of the entire rôle played by carbonic acid in natural waters.

The advantages of the application of lime in this way would be:

1. To prevent the danger of lead poisoning.

Theoretically, this result should be obtained, and the practical experience in England is that no trouble of this character has occurred since the application of chalk was begun.

2. To prevent corrosion and tuberculation in water mains.

With cast-iron pipes this may not be an important matter, but with steel pipes it may be important according to the amount of carbonic acid in the water and the effectiveness of the coating used on the pipes.

3. To permit the use of galvanized wrought-iron and steel service pipes under conditions where it now seems necessary to use more expensive pipes.

This would result in a saving that would partially offset the cost of the addition of the lime.

4. To prevent the red water plague.

There seems to be no doubt but that troubles with rusty hot water are less with hard waters than with soft waters and are greater in proportion to the carbonic acid present. The greatest troubles are found in very soft waters, and especially in soft waters that have been treated with alum and left with a very low carbonate hardness and a considerable amount of carbonic acid. The addition of lime in amounts sufficient to neutralize the carbonic acid normally found would at the same time slightly increase the hardness, and the combined result would be a very material reduction of rusty water troubles.

5. To lessen the need for the use of brass pipe in hot water systems.

Brass pipe is better for hot-water piping than wrought-iron or steel. It costs but little more, as smaller sizes can be used. The reason for this is that brass pipe is smoother and the friction is less, while, moreover, it does not become filled with rust. Yet in cheap building construction steel pipes are likely to be used to some extent in any event, and if the corrosive properties of the water were reduced, there would be less objection to the use of this metal. Thus the people who live in the poorer houses would be supplied with cleaner hot water.

6. To lessen the corrosion of boiler tubes and feed water heaters.

7. And in general to prolong the life of plumbing fixtures.

The possible disadvantages that might result from this treatment are:

1. The slightly increased cost of the water served. Just how much this would be, it is difficult to say. In England it is said to have cost between 50 and 60 cents per million gallons for the chalk process, but in this country the cost of adding lime would be greater, according to the facilities for applying the lime at places inconvenient of access, and whether laborers doing other work could attend to its application.

2. The slightly increased cost of soap by the water consumers. This probably would not amount to more than five cents per capita per year.

3. The disadvantage of using a slightly harder water in the household.

This would not be a serious matter, but it is one worth careful consideration. Waters that have a hardness less than 20 parts per million do not "curdle" with soap.

4. Formation of more scale in boilers.

This would tend to offset the advantages from the lessened danger of corrosion by carbonic acid.

To these might be added certain objections of doubtful importance.

5. A slight increase in the color of surface waters stained with vegetable matter.

This would vary with the water and with the season, but the in-

crease would probably not be more than 10 per cent., and it might be less or even *nil*.

6. A slight deposition of calcium carbonate in the pipe if too much lime were used.

This would depend largely upon the amount present and the presence of organic matter.

7. Effect on the health of water consumers.

There is no reason to think that an increase of hardness from 10 to 20 parts per million would be in any way injurious to the water drinker. No element would be added to the water that is not already there. Calcium is a necessary element for human life. The hygienic advantages and disadvantages of hard and soft waters are still being discussed by physiologists with no signs of agreement. German specialists claim that the presence of lime in water improves the physique, makes stronger bones, and better teeth. On the other hand, specialists in urinary diseases believe that a hard water tends to the frequency of occurrence of calculi and other troubles of the bladder and kidneys. It is a difficult problem to solve for the reason that even in hard water regions the quantity of calcium taken into the system through the water is very small when compared with the amount present in food. The chemical combination in which it enters the body is, however, different. The scientific evidence at present must be regarded as inclusive, but experience appears to indicate that the hardness of water within the limits mentioned is a negligible hygienic factor. This subject is one that needs careful study, for our present ignorance is to be regretted.

These arguments will doutless be given different weight by different individuals. In the writer's opinion, it is by no means sure that decarbonation by the use of lime would be desirable, but in his opinion the method is well worth trying on a practical scale, and it would have to be tried on a practical scale and continued for a few years in order to determine its merits. It is a matter that cannot be decided on the basis of laboratory tests. This is the primary reason for bringing the subject before this Association.

Quantity of Lime Required.

The determination of free carbonic acid is not ordinarily made as a part of water analysis. H. W. Parker and the author * studied this subject in 1901 and collected data for various surface and ground waters under different conditions, from which it appeared that the following quantities of dissolved carbonic acid are likely to be found in New England:

	Parts per Million.
Rain water in country districts,	2 to 4
Rain water in cities,	5 to 20
Surface water supplies, at tap,	2 to 5
Surface water supplies, surface of reservoirs,	2 to 5
Surface water supplies, stagnant strata near bottom,	5 to 25
Surface water supplies, with heavy algæ growths,	0†
Streams from swamps,	5 to 15
Polluted streams,	5 to 15
Ground waters, driven wells,	2 to 40
Dug wells, well ventilated,	5 to 20
Dug wells, badly ventilated,	20 to 50

The most elaborate discussion of the occurrences of carbonic acid in lake waters is that of Birge and Juday.‡

The amounts of carbonic acid in most of the surface water supplies of Massachusetts as delivered probably do not regularly exceed 5 parts per million, though at times they may be somewhat higher. In ground waters, larger amounts are found. To neutralize one part per million of carbonic acid with lime increases the hardness 1.14 parts per million. This is the theoretical amount. Actually, the increase would be more, as commercial lime is never pure CaO. Some of it is sure to be air slaked when used, so that the figures given would have to be increased by indeterminate amounts up to 50 per cent. perhaps. Hence to neutralize the carbonic acid in ordinary surface water would theoretically increase the hardness by 3 to 6 parts per million, and in some cases by a slightly larger amount. In the case of

* On the Amount of Oxygen and Carbonic Acid in Natural Waters. By George C. Whipple and Horatio N. Parker. Transactions American Microscopical Society, Vol. XXIII, p. 103.

† Results may be negative, showing that CO_2 has been taken from the bicarbonates.

‡ The Dissolved Gases of the Water and Their Biological Significance. Bulletin XXII, Wisconsin Geological and Natural History Survey, 1911.

swampy waters, the increased hardness might be as much as 12 or 15 parts per million, and in ground waters, 25 parts per million or even more. Waters that contain more than 5 parts per million of carbonic acid may be considered as offering special problems, of which mention is made later.

TABLE 7.

INCREASE IN HARDNESS RESULTING FROM NEUTRALIZATION OF DIFFERENT THEORETICAL AMOUNTS OF CARBONIC ACID.

Free Carbonic Acid, Parts per Million.	Increased Hardness, Parts per Million.	Quantity of CaO Required, Pounds per Million Gallons.
1	1.1	5.3
2	2.3	10.6
3	3.4	15.9
4	4.5	21.2
5	5.7	26.5
6	6.8	31.8
7	8.0	37.1
8	9.1	42.4
9	10.2	47.7
10	11.4	53.0
15	17.0	79.5
20	22.8	106.0
25	28.4	133.0
30	34.1	159.0
35	39.8	186.0
40	45.5	212.0

Let us first consider the soft waters where the hardness is less than 10 parts per million and the carbonic acid about 5 parts per million. To neutralize this CO_2 would increase the hardness of the water about 6 parts per million. This would increase the amount of soap required to produce a lather by only 32 per cent., as may be seen by Table 8, upon which the determination of hardness by the soap method is based. Even distilled water requires a certain amount of soap to produce a lather. On the basis of calculation made by the writer ("Value of Pure Water," page 24) the cost of the extra soap involved by this slight hardening of the water would be 60 cents per million gallons, plus an additional allowance for air slaking of the lime.

TABLE 8.

VOLUMES OF SOAP SOLUTION REQUIRED TO PRODUCE A LATHER IN WATERS OF DIFFERENT HARDNESS.

(Committee Report on Standard Methods of Water Analysis, first edition, page 56.)

Hardness, Parts per Million.	Soap Solution Required.	Ratios of Quantities of Soap Solution Required Compared to that Required for Water of Stated Hardness.			
		Hd=0.	Hd=10.	Hd=20.	Hd=30.
0	0.70	*1.00*	0.53	0.34	0.25
5	1.02	1.46	0.77	0.50	0.36
10	1.33	1.92	*1.00*	0.65	0.48
15	1.67	2.40	1.25	0.82	0.60
20	2.04	2.82	1.53	*1.00*	0.73
25	2.43	3.47	1.83	1.19	0.82
30	2.80	4.00	2.26	1.38	*1.00*
35	3.18	4.55	2.39	1.56	1.14

The amount of lime required would be 5.3 pounds of CaO per million gallons for each part per million of CO_2. A water that contained 5 parts per million of CO_2 would, therefore, require 26.5 pounds of CaO per million gallons, or 31.2 pounds of commercial lime containing 85 per cent. available CaO. Lime containing relatively small amounts of magnesium would be needed in order not to increase this troublesome element in the water.

To apply the lime as a clear solution would require about 100 gallons of water for each pound of lime, and it would be necessary to have solution tanks in duplicate as well as mixing tanks and stirring devices. This would require daily attendance and would be somewhat troublesome in various ways. A better method would be to apply the lime, after water-slaking, by means of a dry feed apparatus. This method has recently come into successful use in mechanical filter plants. Alum is fed in this way at the filter at Springfield, Mass., and slaked lime is being fed by a dry feed apparatus at Portsmouth, Va. The dry feed is also used in St. Louis. In the quantity used the lime would readily combine with the CO_2 of the water if the dry feed were discharged directly

into the water to be treated. It would thus be possible to place an electrically operated dry feed apparatus in the gatehouse from which the main leads to the distribution system, and after charging the hopper leave the apparatus to feed automatically with very little care.

Application of Lime Before Storage.

A possible advantage of the lime treatment not mentioned above might be a tendency to check the growth of algæ in distribution reservoirs. Algæ and plants contain chlorophyll. Their growth demands sunlight and also carbonic acid. The elimination of carbonic acid would tend to prevent their multiplication. Carbonic acid is absorbed from the air by water exposed to it, up to its limit of solubility for the partial pressure of the CO_2 in the air. But carbonic acid is also produced by animal organisms and by the bacterial decomposition of organic matter. So that if the water that enters a reservoir were free from CO_2, it is not at all certain that it would remain so. It surely would not remain so for a long period. Yet it is quite possible that in distribution reservoirs, where the storage period is short, the elimination of the CO_2 from the entering water would act as a positive check to the growth of algæ and thus tend to reduce the odors that result from their growth. On the other hand, certain algæ have the power of taking their needed CO_2 from the bicarbonates. These species might be able to grow in spite of the lime treatment.

In large reservoirs where the storage is longer, the benefits of liming before storage would be less and such a preliminary application might be a mere waste, increasing the hardness without benefit.

In reservoirs where algæ at times develop to such an extent that there is a natural disappearance of the CO_2 and inroads made on the CO_2 of the bicarbonates, it would be unnecessary to apply lime.

Lime Treatment for Filtered Waters where Alum is Used.

When alum is used to produce coagulation, as in mechanical filtration, a by-product of the reaction of the sulphate of alumina on the dissolved calcium bicarbonate is carbonic acid gas, which remains in solution in the water in a condition of supersaturation until the water is exposed to the air. The amount of CO_2 added

to the water is 6.8 parts per million for each grain per gallon of alum added, or 4.8 parts per million for each 100 pounds of alum per million gallons of water. This is a very substantial increase and is the principal cause of the increase in corrosiveness of mechanically filtered water, although in the case of very soft water it is probably not the only cause. Although this production of carbonic acid has been known since the early days of the use of alum in connection with mechanical filtration, it has not been considered as a matter of sufficient importance to need correction, and as a result many unfortunate cases of the red water plague have occurred. Lately the matter has been taken more seriously, and steps have been taken to neutralize the carbonic acid by the use of lime or soda. Alum coagulated waters thus form a special case, and a very important case, of the general subject under discussion.

Use of Soda Ash.

Sodium carbonate, Na_2CO_3, known commercially as soda ash, might be and sometimes is used instead of lime to neutralize the dissolved carbonic acid. Soda is commonly used in mechanical filtration when the alkalinity of the raw water is not sufficient to decompose the alum added. Its use possesses some advantages over lime when both are applied as a solution, for soda is more readily soluble than lime and it does not increase the hardness of the water. With sodium carbonate a larger quantity of the chemical would be required than with lime. This, together with the fact that its cost per pound is greater, makes it more expensive to use. With the dry feed apparatus in use the principal advantage of soda over lime vanishes, so that in comparing the two the greater cost of soda must be compared with its advantage of not hardening the water. So far as neutralization of carbonic acid is concerned, either chemical is probably satisfactory. Whether or not soda is better than lime for use in supplying deficient alkalinity in the case of alum-treated waters has not yet been settled by chemists. There are some who think that the use of lime gives a better coagulation of the alum and a greater certainty that all of the aluminum sulphate will be changed to hydrate and precipitated, whereas with soda there is a greater possibility of

the formation of basic sulphates of alumina or aluminates, that might go through the filter and afterwards prove troublesome in the distributing pipes, and especially in hot water systems.

Aside from the question of cost, there seems to be no reason why soda might not be used for neutralizing the carbonic acid of natural waters. Indeed, some waters in nature are found to contain sodium carbonate. Thus in the eastern part of New York state many of the well waters have an alkalinity greater than the total hardness of the water.

Use of Caustic Soda. Chemically, caustic soda, NaOH, would be better than Na_2CO_3, but practically it would prove a troublesome substance to apply.

Decarbonation of Waters by Aëration.

When the amount of dissolved free carbonic acid in water exceeds 5 parts per million, its neutralization with lime would be expensive and would increase the hardness of the water by a considerable amount, but when large amounts are present it is possible to greatly reduce them by exposing the water to the air, that is, by aëration.

The quantity of CO_2 held in solution by water depends upon the amount present in the air and the opportunity that the water has of coming in contact with the air. Table 6 shows the solubility of this gas at different temperatures and for different partial pressures of the CO_2 in the atmospheres. The amounts commonly present in waters are in excess of saturation, so that if the water be exposed to the air in thin films a natural reduction of the dissolved CO_2 will occur.

In 1907 some experiments were made at the Brooklyn Polytechnic Institute by Melville C. Whipple and the author, assisted by Charles F. Breitzke, to ascertain the rate at which water would give up its dissolved carbonic acid on exposure to the air. A series of experiments was made by exposing water which contained 30 parts per million of CO_2 to the air in seven receptacles that differed in capacity and in the ratio of the exposed surface to the volume of the water. The depth of the water in these various receptacles varied from 0.2 to 100 centimeters. The experiment was made in a well-ventilated room where the atmosphere was

not greatly different from that out of doors, and the temperature did not rise above 20° or fall below 18° C. After different periods of time samples of water were withdrawn and determinations of carbonic acid made. The following figures give the approximate times required for the carbonic acid to fall from 30 to about 5 parts per million in the different receptacles:

No.	Depth in Centimeters.	Time.
1	0.2	30 minutes.
2	0.7	3 hours.
3	1.0	7 hours.
4	2.0	10 hours.
5	4.5	1 day.
6	25.0	7 days.

The various results were plotted and analyzed mathematically, and from a study of them the following generalization was drawn:

TABLE 9.

Table Showing Amounts of Carbonic Acid Remaining in Water of Different Depths after Standing for Different Periods of Time.

	Carbonic Acid in Parts per Million. Depth in Feet.			
Time of Exposure.	.01	0.1	1	10
0	30	30	30	30
10 minutes,	26	..	..	..
20 minutes,	23	..	..	..
30 minutes,	21	..	..	..
40 minutes,	19	..	..	..
50 minutes,	17	..	..	..
1 hour,	15	25	..	..
2 hours,	7	23	..	..
3 hours,	..	20	..	..
4 hours,	..	18	..	..
5 hours,	..	17	..	..
6 hours,	..	15	25	..
12 hours,	..	6	22	..
1 day,	..	..	18	26
2 days,	..	..	11	24
3 days,	..	..	5	22
4 days,	..	..	..	20
5 days,	..	..	..	18
6 days,	..	..	..	17
1 week,	..	..	..	16
2 weeks,	..	..	..	8

A second series of experiments was made by allowing water containing different amounts of carbonic acid to fall through the air in drops. This was done in the corridor of the Brooklyn Polytechnic Institute, in a well-ventilated atmosphere, the temperature being within the limits of 18° and 20° C.; as before. The water was allowed to flow from an orifice 6 millimeters in diameter for different distances through the air. These distances were 1, 4, 9, 16, 5, 36, 49, and 64 ft., which correspond to quarter-second divisions of time from a quarter of a second to two seconds.

It was found that the stream from the orifice began to break into drops after 0.18 second. At first the drops remained rather close together, but after a fall of one minute the individual drops spread over a circle about 9 in. in diameter, and after two minutes the diameter of this circle had increased to about five feet. Some experiments on the drops showed that the surface of the water exposed to the air was about 12 000 square centimeters for one liter of water. The falling water was caught after the given periods of time and determinations of carbonic acid immediately made. The results were then plotted on logarithmic cross-section paper, with the times as abscissæ and the amount of carbonic acid as ordinates, and it was found that the points fell on straight lines, as theoretically they should do. Some mathematical analyses were made of these results, and from them Table 10 was prepared, showing the reduction of the carbonic acid in the air obtained by allowing the water to fall through the air in drops for different periods of time.

Various series of experiments were made at different temperatures, which showed that, generally speaking, the loss of carbonic acid from water exposed to the air in drops would be 50 per cent. more in summer than in winter. Experiments also showed that the loss of carbonic acid depended upon the time of exposure rather than upon the distance through which the drops fell.

No great degree of scientific accuracy is claimed for these experiments, and the results would have been slightly different if the experiments had been made out of doors, but they showed in a general way that falling drops of water supersaturated with CO_2 require about fifteen seconds to discharge this excess CO_2

TABLE 10.

TABLE SHOWING REDUCTION OF CO_2 OBTAINED BY ALLOWING WATER TO FALL THROUGH THE AIR IN DROPS FOR DIFFERENT PERIODS OF TIME AT 20° C.

Time in Seconds.	Carbon Dioxide, Parts per Million.								
0.18	5.0	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0
0.25	4.7	8.9	12.8	16.8	20.6	24.2	32.0	39.0	46.5
0.50	4.1	6.9	9.3	11.7	13.8	15.8	20.0	23.4	27.0
0.75	3.7	5.9	7.8	9.4	10.9	12.3	15.0	17.4	19.8
1.00	3.5	5.3	6.8	8.1	9.3	10.3	12.4	14.0	15.8
1.25	3.4	4.9	6.2	7.2	8.2	9.0	10.6	12.0	13.2
1.50	3.2	4.6	5.7	6.5	7.3	8.0	9.4	10.5	11.5
1.75	3.1	4.3	5.2	6.0	6.7	7.3	8.5	9.3	10.2
2.00	3.0	4.1	5.0	5.6	6.2	6.7	7.7	8.5	9.2
2.5	2.9	3.8	4.5	5.0	5.5	5.8	6.6	7.2	7.7
3.0	2.8	3.5	4.1	4.6	4.9	5.2	5.8	6.3	6.7
3.5	2.7	3.5	3.8	4.2	4.5	4.7	5.2	5.6	6.0
4.0	2.6	3.2	3.6	3.9	4.2	4.4	4.8	5.1	5.4
10.0	2.2	2.2	2.3	2.3	2.4	2.5	2.6	2.7	2.8
15.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

into the atmosphere. An exposure of two seconds during warm weather ought to reduce the amount of CO_2 from 25 to 30 parts per million to 5 or 6 parts per million. This is about, the limit that can be obtained in practice by aëration in fountains and sprays.

It would be possible to combine aëration by fountains or sprays with the use of lime or soda, utilizing aëration to remove the greater part of the CO_2 and neutralizing the small amount left by chemical means. The alternative proposition would be to prolong the exposure of the water to the air, reducing the CO_2 to the amount required to saturate it. This would not remove all of the CO_2, but the quantity left would be small. This prolonged exposure could be obtained by allowing the water to fall through holes in a series of trays placed one above the other, or to trickle through beds of broken stone or other coarse porous beds, as is done in Germany in connection with the iron removal process. If this were done, adequate ventilation would be all-important, for if the partial pressure of the CO_2 in the air of the bed or between

the trays were increased, the solubility of the gas would be raised and the CO_2 would not leave the water. Weston has described some of these aërators in his paper on the Purification of Ground Waters, published in the Transactions of the American Society of Civil Engineers, Vol. LXIV, page 114.

Conclusions.

On account of the many unknown factors involved in this problem, the author presents this paper without definite conclusions or recommendations, trusting that it may be the subject of an extended discussion and lead to further investigations of some of the doubtful matters, and to a practical trial in some city where the corrosion problem is serious enough to warrant it.

If the problem of corrosion is to be satisfactorily solved it must be approached from two directions, — from a consideration of the metals used and the character of the water itself. The burden of furnishing pipes of good quality rests upon the manufacturers of supplies, but is there not also a burden that rests upon the water-works authorities, namely, that of reducing the corrosive character of the water where this can be done without undue expense and where the sum total of the advantages might more than equal the disadvantages of the required treatment?

Discussion.

John C. Thresh, M.D. (*by letter*).* Although a considerable amount of attention has been given to this subject in England, it has never assumed the importance which appears to be the case in many parts of the United States. In the north and midlands counties surface water supplies are largely used, but very often there are springs on the collecting areas containing sufficient carbonates of calcium and magnesium to neutralize the plumbo-solvency of the surface water. Where this is not the case, decarbonation is attempted. At first, attempts were made to decarbonate by allowing the water to run through channels containing broken chalk. This proved unsuccessful since the chalk soon became covered with a slimy growth of bacteria

* London Hospital, London, England.

which inhibited the solvent action of the carbonic acid in the water. Filtration through beds of limestone was next attempted, but this material also became slimy, and to prevent this the limestone was placed under a bed of sand. This was an undoubted improvement, but experience has shown that it is unreliable. The Candy Filter Company use magnesite, native $MgCO_3$, which is packed in mechanical pressure filters, and the frequent washing appears to keep this clean and active. The plan usually adopted, however, is the addition by means of a mechanical mixer of powdered chalk or whiting, as this gives the most reliable results. Nearly every works has a different kind of mixer; some add the chalk in powder, others in the form of "milk of chalk." They are equally efficient. The chalk deposited at water works when water is softened by Clake's process can be used, but usually the works using waters of such different types are too far apart to render this practicable.

In other parts of England there are waters, chiefly derived from deposits of non-calcareous sands, which markedly act on metal pipes, and the addition of chalk has very little effect. These waters usually contain a little magnesium chloride, and to this constituent I am inclined to attribute the effect. In these cases I have recommended the addition of about two grains of sodium carbonate to each gallon of water.

If properly coated pipes are utilized, no trouble may arise from the use of such a water. If imperfectly or improperly coated mains are used, then trouble arises, as in the following case.

The village of Tiptree in Essex is supplied with water taken from gravel beds, and this had been used for years without giving rise to complaint, save from one person who had laid a long service pipe of galvanized iron, and the water dissolved marked quantities of zinc. Recently the mains were extended to a place named Tudwick, and when completed complaints were received along the routes of the extended mains about the turbidity of the water. A somewhat lengthy special report was prepared on this subject which showed that the water from the old mains was always bright, but that all samples taken from the three recent extensions were always more or less turbid, either when drawn or within a few minutes afterwards. The worst samples were always from the

Tudwick main, which is 2 600 yards long and has no house connection for a distance of 2 000 yards. The water might be merely tinted brown and be fairly clear when drawn, but upon exposure to the air it speedily began to deposit oxide of iron, and in a few hours there would be a marked brick-red sediment at the bottom of the containing vessel. The Tudwick branch pipe is not coated with the ordinary black varnish but with some kind of paint, but the other branches complained of are coated in the usual manner. I obtained samples of these latter, 2-in., 3-in., and 4-in. in diameter, and having plugged one end I allowed them to stand full of water for twenty-four hours. In no case did the water take up more than the most minute trace of iron, and the samples remained perfectly bright afterwards. When, however, patches of the varnish inside were scraped off, the water dissolved marked quantities of iron, and became turbid afterwards when exposed to air. There can be no doubt that in these branch mains the pipes are not thoroughly coated, hence the action of the water.

The analysis of this water shows it to contain in each gallon:

Calcium carbonate	3.5	grains.
Calcium sulphate	1.9	,,
Magnesium sulphate	.7	,,
Magnesium chloride	.6	,,
Sodium chloride	1.7	,,
Sodium nitrate	2.7	,,
Silica, etc.	.4	,,
Total	11.5	

There is nothing here, unless it is the trace of magnesium chloride, to indicate that the water would have any special effect upon metals.

We experience far more trouble with hard waters than with soft waters in Southern England, hence the question of "softening" is much more interesting than that of "decarbonating."

It may be interesting to compare Professor Whipple's table of the hardness of Massachusetts supplies with those of the county in which I am most interested, Essex, with its population of about one and one-half millions.

HARDNESS OF WATER USED IN THE URBAN AND RURAL DISTRICTS OF ESSEX, HAVING WATER SUPPLIES DELIVERED FROM MAINS.

Name of Authority or Water Company.	Source of Water.	Hardness, Parts per Million.
Braintree, urban	Deep well.	160
Braintree, rural	Deep well.	200
Brightlingsea, urban	Deep well.	170
Chelmsford, borough (*a*)	Springs.	320
(*b*)	Mixed spring and deep well.	130
Chelmsford, rural	Deep wells.	40 to 50
	Springs.	100 to 380
Clacton-on-Sea, urban	Springs.	160
Colchester, borough	Deep wells and springs.	160
Dunmow, rural	Springs.	400
	Deep well.	340
Halstead	Deep wells.	270
Herts and Essex Water Company	Deep wells.	300
Metropolitan Water Board	Deep wells and river.	220 to 320
Malden, borough	Deep wells.	75
Malden, rural	Springs.	100
Rochford, rural	Deep wells.	40
Saffron Walden, borough	Deep wells before softening.	370
Saffron Walden, borough	Deep wells after softening.	120
Shoeburyness, urban	Deep wells.	40
Southern Water Company's wells	Deep wells (22).	28 to 700 Average about 80
South Essex Water Company's wells	Deep wells.	125 to 240
Stanstead, urban	Deep wells.	300
Tendring Hundred Water Company's area	Deep wells.	210
Witham, urban	Deep wells.	100
Wyrenhoe, urban	Deep wells.	150

In my annual report on the County of Essex for the year 1910, I made a somewhat detailed study of the mortality statistics of the soft water areas (hardness under 100 degrees), of the moderately hard water areas (hardness between 100 degrees and 200 degrees), and the hard water areas (hardness over 200 degrees), and I present the briefest possible summary for what it is worth.

Deaths per 1,000 Population.

	From All Causes.	From Cancer.	From Phthisis.
Soft water areas	10.2	1.07	.84
Moderately hard water areas	11.7	.86	.93
Hard water areas	10.2	.73	.93

The use of lime for removing free carbonic acid has invariably proved unsatisfactory, and I know of no place where it is employed. I have experimented with it for preventing the action of certain waters on lead, but the results were most disappointing. It is well known that when used for softening water a large number of bacteria are precipitated with the calcium carbonate, and remarkably purifying effects have been obtained at works under my control when the water from deep wells had become polluted. To obtain uniformly satisfactory results, filtration had to be discarded, and the water allowed to clarify entirely by subsidence. When this was done a water corresponding to most efficiently slow sand filtered water was produced continuously.

Decarbonation of water is also practiced here for the removal of iron from waters in which it appears to exist as a ferrous bicarbonate. Exposure to air by flowing in cascade is not always sufficient, but the addition of a little chalk or lime prior to aëration causes the removal of all the iron. The removal of the last trace of carbonic acid is exceedingly difficult, and I was never able to accomplish it when carrying out experiments on the action of distilled water on lead.

Professor Whipple does not refer to the waters which do not dissolve lead yet erode it. This erosive action appears to be due to the presence of oxygen, and the solvent action to the presence of oxygen and carbonic acid. When a sufficient quantity of carbonates is present apparently a very insoluble oxy-carbonate of lead is formed which may entirely prevent the action of the free carbonic acid unless present in an unusual amount. If the water does not contain the requisite quantity of carbonates and very little carbonic acid, the lead becomes coated with an easily removable film of oxy-hydrate of lead; that is, "erosion" takes place. If a sufficiency of carbonic acid is present, the lead enters solution and the water has a "solvent" action.

It follows, therefore, that a water may be decarbonated and yet have an action upon lead pipes. Such a water when placed in a shallow Petri dish in such volume as just to cover a piece of bright lead will show an erosive action in a very short time; whereas if placed in a deep, narrow tube with the piece of lead several inches beneath the surface the erosion may be so slight, even after twenty-four hours, as to be barely discernible. The effect appears to depend upon the amount of oxygen dissolved in the water. Are these erosive waters dangerous if passed through lead service pipes? I should like the opinion of any persons who may have had experience with such waters. So far as my experience extends, they are not dangerous. Possibly the interior of the pipe, being free from air, becomes coated with an insoluble deposit which prevents any further action of the water.

Mr. E. E. Lochridge (*by letter*).* Mr. Whipple has presented much information in this paper, and while it will undoubtedly be surprising to many that a water of a high degree of purity can be so troublesome, nevertheless, with the further knowledge which is bound to come in this matter, it will soon be an accepted fact that the soft waters of this region have a certain corrosive quality which is troublesome with some kinds of pipe.

Since the trouble experienced with red water in some parts of Springfield, I have taken every opportunity to note the conditions in other cities with natural water supplies which are probably of about equal hardness. I find that the red water trouble in many of these places is fully as pronounced, and in many cases more so, than was the case in Springfield. The water supply, however, being a natural supply and subject to the variations of color, etc., of such a supply, do not give occasion for comment on the higher colored hot waters that is the case when a filtered water is produced of substantially uniform quality throughout the year.

The public is becoming more critical on the question of the quality and appearance of water furnished from public supplies, and as filters and other means of purification are extended, this question will become more and more pertinent. If anything can be done to relieve the situation as is suggested by Mr. Whipple it

* Chief Engineer, Springfield Water Department, Springfield, Mass.

is well worth studying, but in the meantime, it would seem to me that water-works people should encourage the use of such pipes as will give a uniformly high grade of service for both hot and cold water, and this can be done with little additional cost at the present time.

INSULATION OF JOINTS IN PIPE LINES.

BY WILLIAM R. CONARD, INSPECTING ENGINEER, BURLINGTON, N. J.

[*Read February 12, 1913.*]

Some years ago it was my privilege to get pipe for carrying high-pressure gas, or rather that was the term used in speaking of it, and the thought was that it might be of interest to the New England Water Works Association to have a short description of the manner in which these pipes were laid in an endeavor to get a line as nearly proof against electrolytic action as possible.

The pipe were purchased and laid by the Meriden Gas Light Company from their Meriden plant to Southington and Cheshire, Conn., in all about 15 miles of 6-in. pipe.

The pipe were of the ordinary bell and spigot type with the bell made 5 in. deep and with no lead groove (see Fig. 1), and were tested to 50 lb. of air per sq. in. at the foundry in addition to the regular hydrostatic test.

In laying these pipe the joints were made up by placing at the base of the bell $\frac{1}{4}$-in. wooden ring, oil-soaked; the spigot of the pipe next to be used was then encircled with a rubber band about $\frac{1}{16}$ in. thick and $2\frac{1}{2}$ in. wide placed about $5\frac{1}{2}$ in. from the spigot end of the pipe to prevent an iron ring, afterwards put on, coming in contact with the pipe; the pipes were then put together, the spigot going home against the wooden ring, and about $1\frac{1}{2}$ in. of untarred jute packing calked tight; instead of lead being poured in to make the rest of the joint, an insulating compound about 3 in. deep, black in appearance, which melts readily at 200° F., was poured, after which a square rubber packing was put on, and then a No. $4\frac{1}{2}$ Dresser coupling was applied to the joint and clamped tight (see Fig. 2).

To those unfamiliar with the Dresser coupling, I would say that it consists of two split clamp rings; one split clamp ring fitting around the outside of the base of the bell, the other around the outside of the spigot end of the pipe, entering the bell, with a 1-in. square rubber packing ring between it and the bell. The two

rings are connected and drawn towards one another by four bolts, one ring pressing against the square rubber packing.

The line, after laying and in sections, was tested with 20 lb. per sq. in. air pressure, and all joints found tight.

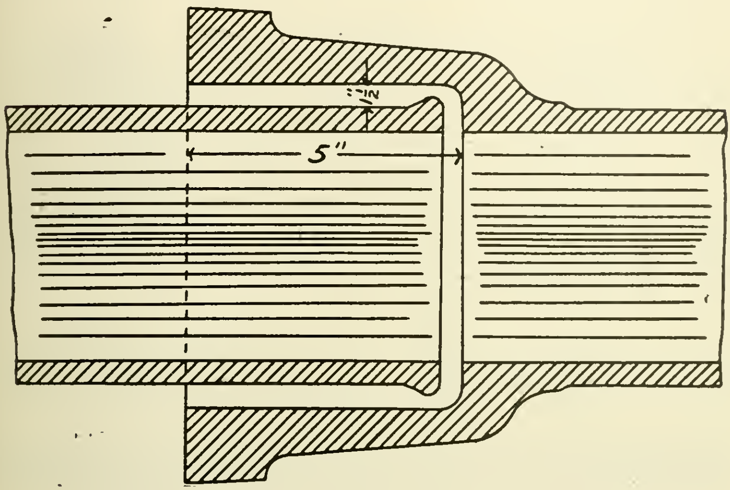

FIG. 1.

CROSS-SECTION OF BELL AND SPIGOT.

Joints made up in this manner are as flexible as poured lead joints, acting just as readily as expansion joints, and electric tests made shortly after installation indicated no flow of electricity at all, although, the entire pipe line parallels an electric car line.

The expense of a line like this figured about three times greater than for an ordinary lead joint, but for a gas line it was considered very desirable that it should be no conductor of electricity.

It is probably true that the rubber used in these joints will in time disintegrate, but it is also true that it will last for quite a number of years, for the moisture in the earth and the absence of exposure to the atmosphere should keep the volatile particles of the rubber alive for a long while.

As an insulated joint to prevent pipe lines from carrying stray currents of electricity it would appear that it would be fully as serviceable for water as for gas lines.

On the line to Southington these insulated joints were installed on every other pipe, and on the line to Cheshire on every joint.

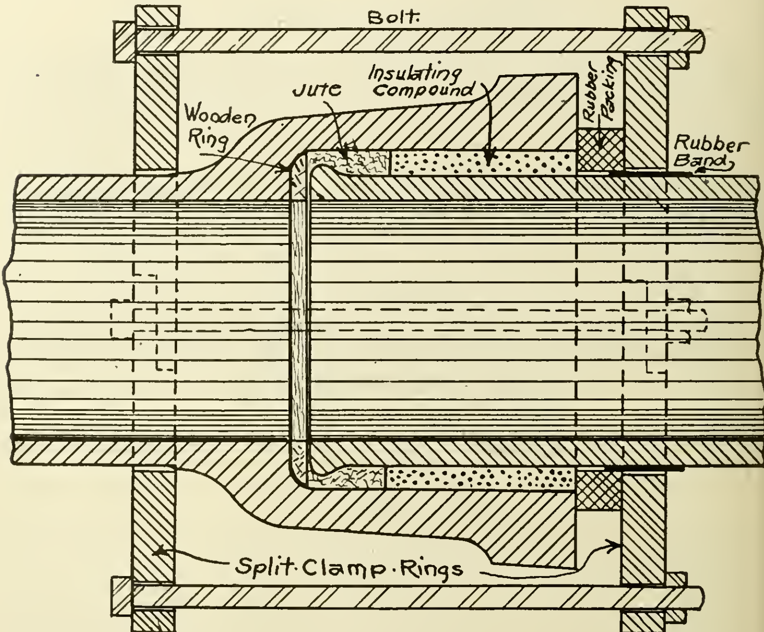

FIG. 2.

THE JOINT MADE UP.

Since writing the above I learn from Mr. Brackett, chief engineer of the Metropolitan Water Works, that rubber insulated joints have been used by them and were successful when installed, but due to some cause not definitely determined, though thought to be due to a large amount of current charging the pipe from a heavy electric storm, the rubber was in part carbonized and thereby became a conductor rather than an insulator. It would appear, therefore, that so long as electricity can be prevented

from collecting in large volume, the joint described is an efficient insulator, but one can never tell what is going to happen during an electric storm. If the rubber once becomes carbonized or loses volatile properties, it fails as an insulator.

DISCUSSION.

Mr. Richard D. Chase.* It seems to me that this joint, so far as the filling of the space between the hub and spigot, is well adapted to the purpose. However, if I read the drawing aright, there is nothing but a thin layer of rubber underneath the clamp in front of the hub to prevent a current of electricity from passing from the pipe back of the hub through the clamps and bolts and again into the pipe. Dependence is placed on a piece of rubber apparently about an eighth of an inch thick, which would be very likely to disintegrate. If some way could be found of insulating the bolts from the clamps, I should think the joint would be very much better. It might be possible to insert in the bolt-holes a porcelain thimble so as to break the connection around the hub.

Mr. Leonard Metcalf.† The statement in regard to the experience with the carbonizing of the rubber is interesting, especially in view of the fact that rubber joints have been used abroad in suction pipe lines to a very considerable extent and very effectively, I believe, and, so far as I have chanced to hear, they have not given any trouble of that sort. I think such joints have been used abroad certainly for periods of upwards of ten years. Of course a very pure grade of rubber is required.

Mr. Chase. In the case Mr. Metcalf mentions, the rubber would be inside the hub?

Mr. Metcalf. It would.

Mr. Chase. If so, it would be somewhat protected. In this particular joint it seems to me that reliance is placed entirely on a thin sheet between the clamp and the pipe, where it would be exposed to decay.

Mr. Metcalf. I think Mr. Chase's point is a good one. That could be obviated, however, by making the casting which rests

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* New Bedford, Mass.
† Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

over the bell cup-shaped, so it would come down and close over the metal of the bell.

Mr. Robert S. Weston.* The rubber joints, as used abroad, consist simply of a ring of very pure rubber, and are squeezed into the joint by putting the rubber ring over the spigot and rolling it into the bell. Rubber, as you know, absorbs about 25 per cent. of its weight of oxygen, and becomes hard and brittle. But if it be kept away from the air and immersed in water it ought to last indefinitely. We have kept rubber tubing in the laboratory in water without any deterioration for several years. I think the practice abroad is to use these joints almost entirely on their suction lines. They drive the pipe home and then cover the rubber ring with moist clay.

* Consulting Sanitary Engineer, Boston, Mass.

QUANTITATIVE ESTIMATION OF GROUND WATERS FOR PUBLIC SUPPLIES.

BY MYRON L. FULLER, CONSULTING ENGINEER, BOSTON, MASS., FORMERLY IN CHARGE OF GROUND WATER INVESTIGATIONS IN THE EASTERN UNITED STATES FOR THE UNITED STATES GEOLOGICAL SURVEY.

[*Read March 12, 1913.*]

EXISTING CONDITIONS.

The development of water supplies from surface sources has long received the careful consideration of hundreds of engineers, including many of the most prominent in the country. The questions involved have been earnestly attacked, thoughtfully considered, carefully weighed, and painstakingly solved, not only for the large cities, but for the smaller municipalities, towns, and villages as well. The best thought of our best men has been freely given to the subject.

Ground-water supplies, on the other hand, with a few exceptions, such as the Long Island supply, investigated by the New York Commission on Additional Water Supply, have rarely received, here in the East, more than the passing attention of engineers. The problems, lying, as they do, outside the usual limits of the engineer's training and experience, have seldom been studied with anything like the same degree of thoroughness as the surface supplies. Too often, he has assumed, because they have been obscure to him, that the occurrence and movements of ground waters follow no definite laws, and that the securing of adequate supplies is, in most cases, a mere matter of luck.

In reality, the principles controlling the collection, absorption, storage, motions, and recovery of the waters within the ground are as definite as those governing the waters upon the surface, and are worthy of the same serious consideration that has been given to the latter. If this is given them, their problems are equally open to solution, and the prediction of supplies will become a matter of comparative certainty rather than of mere conjecture.

It should be emphasized, however, that the problems fall only in part within the province of engineering. The greater part, on the contrary, are geological and require a degree of training and experience found, as a rule, only in the specialist.

Conservation and efficiency are the watchwords of the day, and nowhere is there more opportunity for their successful application, or more room for their development, than in the utilization of ground waters for public supplies. At the present time, municipalities as well as corporations are to an alarming extent groping in the dark in the search for such supplies. I believe that, taking New England as a whole, not less than 25 per cent. of the expenditures for wells is wasted through injudicious location of wells, improper methods of sinking, and unnecessary depth of drilling. In many localities the waste rises higher, and occasionally the entire outlay is a total loss. When it is remembered that the wells sunk each year are numbered by hundreds, the heavy loss involved even by a 25 per cent. waste will be appreciated.

It is the purpose of this paper to outline briefly what has been established as to the water-bearing capacities of various rocks and unconsolidated materials, and to indicate the principal steps necessary in quantitatively estimating the ground waters available for public or other supplies.

BASIS OF QUANTITATIVE ESTIMATION OF GROUND WATERS.

The basis for the following statements and conclusions concerning the quantitative determination of ground waters is the work of the United States Geological Survey, on which organization the author had for some years the direction of the ground-water investigations in twenty-seven of the eastern states, supplemented by later experience in connection with consulting work for San Francisco and other cities and corporations.

For many years, the Geological Survey has had a considerable number of parties constantly in the field during the working season, and has accumulated and published a large quantity of valuable data on ground waters in all parts of the country and in all classes of materials.

Among the most important data from the standpoint of the members of the New England Water Works Association are those pertaining to the quantitative occurrence of water in the numerous types of sedimentary or glacial deposits, or in the many different varieties of rocks. The government investigations of these problems have, in many instances, been "type studies." and although often based on conditions in areas of comparatively limited extent, are, nevertheless, susceptible of general application to materials of the classes investigated wherever they may be encountered.

For example, the results of the Long Island investigations by the New York Commission and the United States Geological Survey may be regarded as standards of information for glacial sand-plains throughout the country. The government's conclusions concerning the granites of Connecticut are equally applicable to most of those of Massachusetts, Maine, New Hampshire, or Vermont. The investigations of the limestones of Ohio, the slates of Maine, the sandstones of the West, and the glacial drift throughout the East are likewise applicable to similar deposits wherever they may be found. It is through such studies that we are able to undertake the quantitative estimation of ground waters with a reasonable degree of confidence.

FACTORS IN GROUND-WATER ESTIMATES.

In any attempt to estimate available ground waters, a certain number of factors common to all localities must be carefully considered if the deductions are to be of value. These may be stated as follows:

1. Nature of water-bearing materials.
2. Storage capacities of water-bearing formations.
3. Availability of supply.
4. Area tributary to wells.
5. Velocity of underflow.
6. Rate of replenishment.

Those of you who are familiar with well drilling will, I feel sure, agree with me that in the vast majority of cases the

knowledge of the foregoing factors is practically confined to the first. In not more than one out of ten wells is there an *adequate* knowledge of storage capacity, rate of yield, or tributary area, while in hardly one in a thousand is the velocity or rate of replenishment seriously investigated.

All the factors enumerated are, nevertheless, susceptible of approximate determinations and, when known, greatly restrict the range of errors of estimation.

DETERMINATION OF WATER-BEARING MATERIALS.

The determination of the character of materials to be encountered in a well is not so simple as might appear. In many instances the immediate surface affords but little indication of what lies beneath. The glacial deposits which overlie the rock practically everywhere in New England are highly variable in character and may range from loose sand to dense hardpan within an interval of a few feet. The depth or thickness of such deposits is likewise subject to abrupt changes within short distances.

The character of the solid rock lying beneath the surface deposits is, in many instances, even more difficult to determine, for although some formations are of nearly uniform character over wide areas, others change rapidly from point to point. In a large number of cases the changes occur beneath valleys where the rock is deeply buried.

The determination of the character of the rocks at considerable depths below the surface is seldom an impossible task. On the contrary, it may usually be made with a reasonable degree of accuracy. But the work is properly that of the geologist, and the judgment of the layman or of the average driller or engineer, unless he has had extended experience with geological problems, will ordinarily be of little value if the conditions are at all complicated. Too often he does not even know whether they are complicated or not.

The importance of an accurate determination of the character of the water-bearing materials will be apparent to all, for upon it will depend the storage, the rate of yield, and the quality of the supply. There can be no question that the best information

obtainable should be secured before drilling is begun if the work is to be conducted in the most intelligent and economical manner.

STORAGE CAPACITIES OF WATER-BEARING FORMATIONS.

The volume of the ground-water depends directly upon the containing material, and if a quantitative estimate is to be made, the nature of the water-bearing bed must be accurately known, for upon it depends the character of the storage, — whether in pores, in joints or fissures, in cleavage or schistosity plains, in solution passages or cavities, etc.

Here again an intimate knowledge of the occurrence of ground waters is indispensable. Every one knows that open cavities are encountered in rocks, but comparatively few realize that such openings are found only in limestones, and that in our granites, sandstones, and slates there is not the remotest possibility of encountering such a passage.* All of you know that water is found in the joints or fissures of granites, but how many are there who appreciate that the width of these is seldom more than a twentieth and is often less than a fiftieth of an inch, and that few of them extend more than a few hundred feet, thus cutting off the possibility of a distant supply. Yet these and other similar factors are of vital importance in the estimation of the yield of proposed wells.

AVAILABILITY OF SUPPLY.

The availability of ground waters, or the quantity yielded to wells, has no relation, strange as it may seem, to the storage capacity of the materials in which they occur. Often the formations containing the largest supplies will yield the least. In the following table, the first column indicates the volume of water actually contained in rocks and soils of various types, while the second shows the usual yield (or available supply) from the pores.

* The supposed openings in the latter rocks, assumed to exist because of the sudden dropping of the tools while drilling, are in reality simply soft streaks, often of a cheese-like consistency, consisting of clayey products of decomposition known as selvage through which the drill penetrates at a single stroke. They are the result of the circulation of water within the rock, and will, therefore, naturally afford considerable water to wells.

TABLE 1.

Porosities and Yield of Rocks and Unconsolidated Materials.

Material.	Storage Capacity or Porosity. Per Cent. of Volume.	Normal Yield to Drilled Wells from Pores.* Per Cent. of Volume.
Quartzites (average)	½	None
Granites (average)	1	None
Slate and shale (average)	4	None
Limestone and marbles (average)	5	None
Sandstones	5 to 25	1 to 15
Gravel (mixed with sand)	20 to 30	10 to 20
Sand (medium to coarse)	30 to 40	10 to 25
Sand (fine)	30 to 40	5 to 20
Clay	40 to 70	None
Till or bowlder-clay	20 to 60	0 to 20

The table does not, by any means, tell the whole story. For instance, while clays will yield practically nothing to wells, they are of great value as feeders to underlying rocks, to which they slowly give up their water. In many instances, as at Boston, the capacities of rock wells are probably doubled by the presence of their clay covering. Again, while the sandstones may show an ultimate yield of from 1 to 15 per cent. of their total supplies, the water often enters a well too slowly to be of value as a source of supply.

In fact, there are so many modifying conditions that the determination of the probable quantity of a proposed supply demands a thorough knowledge of ground waters and a careful study of local conditions.

AREA TRIBUTARY TO WELLS.

It hardly needs to be called to your attention that the ultimate quantity to be derived from wells at a given point will be, other things being equal, proportional to the extent of the tributary area. It is not always, however, a simple matter to determine the distance from which water will find its way to a well, and a separate determination, based on a careful examination, must be made at each locality. There are, however, certain general

* The figures in this column do not include the yield from fissures, joints, or cleavage planes. Water remaining in rock is largely residual moisture held by capillarity.

facts regarding the distances traversed by ground waters which should be of interest to members of this Association. Some of these are summarized below.

TABLE 2.

DISTANCES TRAVERSED BY GROUND WATERS.

Material.	Usual Distance of Source from Well.	Ordinary Maximum Limit of Transmission in United States.
Surface sands and gravels	Less than 1 mile.	25 miles.
Deep sands and gravels (beneath clay or other confining layers)	Several miles.	100 to 200 miles.
Sandstones near surface	$\frac{1}{2}$ to 1 mile.	5 to 10 miles.
Deeper sandstones	Several miles.	100 to 300 miles.
Limestones near surface	$\frac{1}{2}$ to 1 mile.	10 to 20 miles.
Deeper limestones	Several miles.	100 to 200 miles.
Slate or shale near surface	Less than 500 ft.	Rarely over 1 mile.
Deeper slates or shales	Possibly several miles.	Rarely over 10 miles.
Granites	Less than 1 000 ft.	Rarely over 2 or 3 miles.

NOTE. — Some rocks are water-bearing at greater distances from the outcrop than is indicated in the table, but it seems probable that the water has been absorbed by capillarity from overlying materials rather than derived by transmission from remote catchment areas.

The wide variations in the areas tributary to different sets of wells will be appreciated from an examination of the foregoing table. The problems of source and tributary area are, naturally, geological in their nature and will require the services of a geologist for their solution. To one trained in this line, however, they will ordinarily present few difficulties.

THE VELOCITY OF UNDERFLOW.

As in the case of a surface stream, the quantity of available ground water at a given point is determined by multiplying the cross-section of the moving water body by the velocity of its movement. This will give us the normal underflow, or, in other words, the maximum available supply; for, although it is possible to pump for a time from the reservoir (accumulated storage) within the ground, no more water can be obtained in the long run than is normally flowing within the limits of the area tributary to the wells.

Only in a very few cases has the velocity of underflow been determined in connection with the development of municipal supplies, although it is perfectly practicable where the water occurs in unconsolidated material of reasonable uniformity, and would undoubtedly prevent the waste of large sums in injudicious prospecting or unwarranted development.

The most successful process of measuring underflow is the Slichter method, described on page 268. It can be applied by any mechanical or other engineer, but for the interpretation of results, and more especially the determination of the extent of the tributary area, usually demands considerable geological knowledge and experience.

RATE OF REPLENISHMENT.

An accurate determination of the rate of replenishment is of the first importance, for, no matter how great the storage and how large the tributary area, a large permanent supply will be obtainable only when the average absorption is at least equal to the quantity of water withdrawn.

In New England, the determination of the rate of replenishment is a comparatively easy matter, for we are here dealing with an area of abundant and well-distributed rainfall, relatively low evaporation, and fairly simple absorptive conditions. In the western arid and semi-arid regions, on the other hand, the problems are more complex. There, the rainfall and evaporation are very irregular and it takes but little to disturb the balance and change a net gain to a net loss. When the loss by evaporation becomes greater than the rainfall, the replenishment can take place only by absorption of water from the streams, which often pour down more or less transient floods after heavy rainfalls. In such instances, careful field observations, supplemented by laboratory tests to determine porosities and rates of percolation, are necessary to determine the rate of absorption and additions to the ground-water reservoir.

In the East, the problem requires a careful computation of the rainfall and an analysis of its seasonal distribution, together with a similar investigation of seasonal evaporation and plant

transpiration, and an accurate determination of the porosity, size of grain, rate of percolation, nature of vegetation, and other minor factors regulating absorption.

LIMITED VALUE OF TEST WELLS AND PUMPING TESTS.

Water-works men and engineers have frequently remarked to me that, after all, the only way to tell whether or not one has a supply is to put down a test well and make a pumping test.

With this view, I do not at all concur, for it may be readily shown that pumping tests come far from furnishing complete data as to the availability of permanent supplies. What a pumping test shows and what it does not show is concisely summarized the following table.

TABLE 3.

Data from Pumping Tests.

Pumping tests *show*	Pumping tests *do not show*
1. Character of material at well.	1. Average character of material of tributary area.
2. Presence or absence of water at time of test.	2. Permanency of the supply.
3. Rate of delivery when water is at maximum height.	3. Rate of delivery from depleted reservoir.
4. Quality of water at start.	4. Quality of water after continued pumping.
	5. Direction of movement of ground water.
	6. Velocity of ground-water movement.
	7. Source of water.
	8. Extent of tributary area.
	9. Rate of replenishment.

That a knowledge of the materials at the well is insufficient is indicated by the fact, long known to ground-water engineers, that it is the average section for the whole area and not its character at a single point that determines both storage and movement of the ground water. This is manifestly not furnished by a single test well.

The pump may deliver during a test very large volumes of water, but, except where the supply is very limited, and hence

readily depleted, the test shows nothing as to the supply permanently available. Many wells tap ground-water reservoirs containing the accumulated supplies of long periods, but the fact that half a million gallons may be withdrawn daily for a few days is no indication that the permanent yield, taking it year in and year out, will be more than a small fraction of this amount.

When the water table stands high in the ground, the entrance of the water into a well is relatively rapid, but the rate of entrance declines as the water table becomes lowered through depletion. The extent to which the supply will be affected can be determined only by a study of the tributary area, velocity of underflow, and rate of replenishment, no indications of which are afforded by pumping tests.

It is well known that in heavily pumped wells the quality of the ground-water supply often deteriorates with the passage of time, although possibly not for some months or years, but the nature and extent of the change is to be predicted from a study of the character of the materials and of the geological structure rather than from a necessarily brief pumping test.

The direction of movement of the ground waters is of considerable moment in determining the liability of pollution by contaminating matter from the surface, or of the likelihood of the penetration of sea water or other mineralized waters from clays, shales, bog iron ores, peats, etc., but is not usually indicated by the pumping test.

The paramount importance of a thorough knowledge of the rate of underflow, the source of the supply, the area tributary to the wells, and the rate of replenishment has been already indicated. Without such knowledge, there can be no clear conception of the problem, and the search for a supply will be mere guesswork. That the information is not to be gathered from the results of pumping tests will, the author thinks, be conceded by all.

Notwithstanding the limitations of the data furnished by pumping tests, I do not wish to be understood as maintaining that such tests are without value. On the contrary, they are of much value when their limitations are understood. They should, however, be regarded as adjuncts to ground-water investigations rather than as final in themselves.

QUANTITATIVE ESTIMATION OF GROUND WATERS.

Having touched upon some of the more important general problems involved in the determination of available ground waters, the estimation of the prospective supplies to be secured from the various rocks and unconsolidated deposits, especially those of New England, may be properly considered.

It will be found that considerable space is devoted to the occurrence of ground waters in formations which, like the granitic rocks, are of comparatively small importance as sources of public supplies. The reason for this is that very little has been published concerning the yield of rocks of these types, at least in a form readily available to water supply officials. Such rocks are, nevertheless, likely to become of increasing importance as supplementary if not primary sources of supplies for small villages and towns.

AVAILABLE GROUND WATERS IN GRANITIC ROCKS.

Granitic rocks, with which are here included traps, the various gneisses or banded granites, and the laminated crystalline schists, constitute the country rock underlying more than half of the entire area of New England, and, on the whole, are the least prolific as regards water supplies of any class of rock we are likely to encounter in this region. The range of yield is, nevertheless, fairly well established, and while individual wells may vary greatly, the quantity of water that would be available to a series of wells, such as those of a small water supply system, may be estimated with a fair degree of approximation.

Controlling Factors. — The water in granitic rocks includes that in the pore spaces between the grains and that in the joints or seams and other fissures. The former have been found by numerous laboratory tests to average about 1 per cent., or about 0.3 of a quart per cubic foot. Within a radius of 500 ft. from a 300-ft. well the supply thus stored would be approximately 17 600 000 gal. Unfortunately, however, all of this is firmly held within the rock by the force of capillarity, and hardly a drop is yielded to wells.

The supplies of the wells ordinarily come from a single source, the joint planes or seams which cut the rock in various directions

from vertical to horizontal. These are familiar to all of you who have ever examined a large quarry. The common vertical or highly inclined joint is that represented by the broad, smooth, iron-stained surface that often forms one of the sides of the quarry or that cuts the quarry face as a vertical seam. Plate X shows several such joints dividing the rock into a series of sheets. The horizontal joints are the flat or curved seams found in the upper portions of most hillside quarries, as show in Plate XI. They are poorly developed and often practically absent in valleys or where the hills or slopes are thickly covered with earth or other deposits.

The number and character of the joints within the area tributary to a well are not, however, the factors ultimately determining the supply, for the water so held would be ordinarily exhausted within a few hours if it were not for replenishment, which is regulated by the character of the covering over the rock and the topographic conditions in the vicinity.

Some years ago, Mr. E. E. Ellis, of the United States Geological Survey, spent a season under my direction in the investigation of the granitic rocks of Connecticut. His results* are the basis of many of the following statements.

Considering the granitic rocks of New England, of which the Connecticut rocks are fair representatives, it appears that the average spacing of the vertical or highly inclined joints of a given series is something over 10 ft., but when those of different directions or inclination are included, it probably averages more nearly 5 ft. Horizontal joints often occur as close as a foot apart in the upper 20 ft., but at 50 ft. they range from 6 to 30 ft. from one another.

At the surface, the vertical joints are frequently wide and gaping, but they become much narrower with depth, fully half of their number dying out in the first 150 ft. The average width has been estimated, from careful study of a large number of quarries, at 0.01 in. at depths of 50 to 300 ft. The horizontal joints are rarely more than mere seams.

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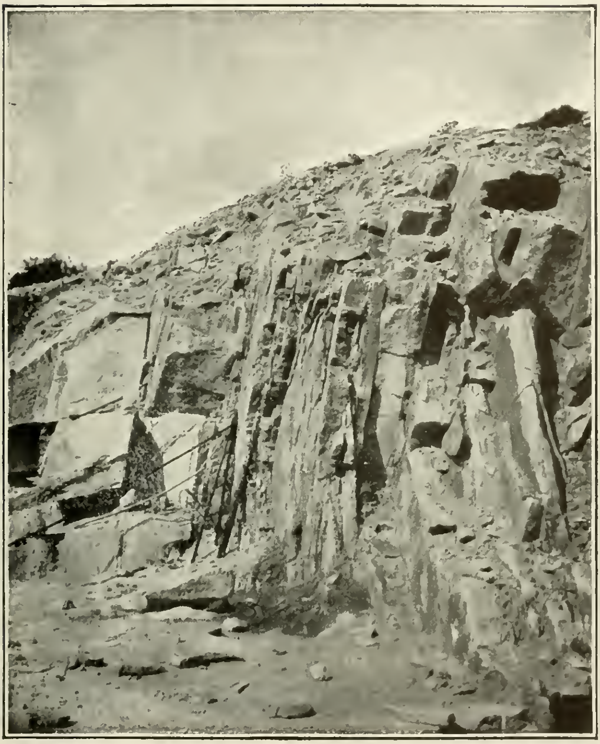
* Occurrenceof Water in Crystalline Rocks. United States Geological Survey, Water Supply Paper 160, pp. 19–28. Ground Water in the Crystalline Rocks of Connecticut. Water Supply Paper 232, pp. 54–103.



SHEET OR PARALLEL JOINTING IN GRANITE. (PHOTO. BY U. S. GEOL. SURV.)
SUCH SHEETED ZONES ARE OFTEN PERSISTENT FOR LONG DISTANCES
AND GENERALLY YIELD CONSIDERABLE WATER TO WELLS.

Horizontal Jointing in Granite, Showing Seepage of Water from Joint Planes. (Photo. by U. S. Geol. Surv.) Jointing of this Type is Best Developed at the Surface, and Yields Water to Shallow Wells.

The ordinary vertical joint commonly extends for several hundred feet before dying out or joining another fracture, while the principal or master joints, especially those along which there has been faulting, may extend some miles. The sheeted zones formed by a series of closely spaced parallel joints, Plate X, are also rather persistent. It is to be noted, however, that the portions of joints sufficiently open to be water bearing are usually of limited extent. This is indicated by the fact that salt water rarely penetrates more than 500 ft. from the coast and has never, so far as known to the writer, entered wells located more than 1 000 ft. away. The continuity of the horizontal joints rarely exceeds a few hundred feet.

The attitude or inclination of the joints is an important feature, for unless they are more or less inclined they will not be intersected by a well. In the average New England well in granitic rocks, the number of inclined joints encountered is approximately as follows: 0–100 ft., 4; 100–200 ft., 3; 200–300 ft., 2; 300–400 ft., 1; more than 400 ft., less than 1 per 100 ft.

In addition to the vertical or inclined joints of the regular systems, there must be a certain number of connecting joints joining the various members of a series if a well is to afford any considerable supply. Fig. 1 shows the nature of such an intersecting system.

From the number and character of the joints it is possible to estimate the quantity of water stored in the rocks. I have elsewhere* estimated that with a double system of joints, each with the fractures at an average distance of 5 ft. from one another, there would be about 1 cu. in. of water to 125 cu. ft. of rock. This would be equivalent to approximately 8 000 gal. within a 500-ft. radius of a 300-ft. well.

Since this amount of water would be exhausted by a few minutes' pumping, it is apparent that (1) the number and width of the joints must be larger than estimated, (2) the distance from which water is drawn must be greater than assumed, or (3) the supply must be replenished as rapidly as withdrawn. From the studies of scores of quarries we know that there is little chance for the

* Total Amount of Free Ground Water in the Earth's Crust. United States Geological Survey, Water Supply Paper 160, p. 70.

first, and from the fact that salt water is drawn in from the sea for only short distances, while wells more than a few hundred feet apart rarely affect one another, as they would be sure to do if the joints extended for any considerable distance, it is equally certain that in the majority of cases the water can come from little if any greater distance than postulated. There is every reason to believe, therefore, that the supplies of wells in granitic rocks come, in practically all cases, from the coverings or feeders of overlying material, the quantity being determined by the nature of the feeder and the width of the joints through which the water is transmitted to the well. The intercommunication of soil and rock waters is further indicated by the head of the

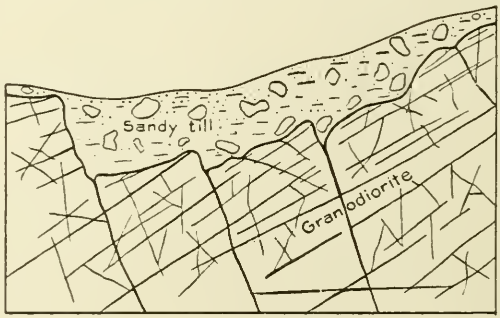


FIG. 1.

DIAGRAM SHOWING INTERCOMMUNICATION OF JOINTS, AND A SURFACE "FEEDER" OF TILL. (H. E. GREGORY.)

waters in the rock wells, which is practically always controlled by the level of the adjacent surface waters, although direct connection may be entirely cut off by the well casings. The chemical differences in the characters of the waters so often noted are the result in part of differences in source and in part of chemical reactions or occasionally of mechanical filtration.

The effect of the soil covering upon the entrance of waters into a rock must be apparent to all. If the rock surface is bare, the rain will be shed, as from the roof of a house, without absorption. If, on the other hand, it is overlain by a porous soil (Fig. 1), the rain will be taken up as it falls and held as in a sponge, to be

subsequently slowly yielded to the rock beneath. The thicker the soil mantle, the greater and more permanent will be the supply. Vegetation, to a certain extent, aids absorption, but it more than doubles the loss by evaporation and transpiration. Frozen soils will naturally be practically non-absorptive.

Topography, or surface relief, also has much to do with the yield of wells in granitic rocks. On slopes, the water is shed quickly, and the feeders above the rock hold less water. In valleys, if the covering is at all thick, the materials over the rock surfaces are always saturated. On the broader hills and on plateaus or upland plains the quantity of water held in the feeders is less than in the valleys but more than on the slopes.

Yield of Wells in Granitic Rocks. — Having considered the various factors controlling the ground-water supplies in crystalline rocks, it remains for us to apply them to our estimates of yield. The results may be most concisely shown by means of a table.

TABLE 4.

Estimated Yield of Wells in Granitic Rocks.
(Gallons per Minute.)

Depth of Well. (Feet.)	Diam. of Well. (In.)	No Cover to Rock.			Medium Cover to Rock.			Thick Cover to Rock.		
		Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.	Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.	Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.
100–200	4	3	4	6	8	15	20	15	20	25
,,	6	4	5	8	10	20	25	20	25	30
,,	8	5	6	10	12	24	30	25	30	35

The figures of the above table are the average estimated permanent yields. Individual yields may be considerably greater or less than indicated, ranging from 0 in the smaller wells on slopes to over 200 gal. a minute in the larger wells in valleys. Initial yields are sometimes, but not always, much higher than the permanent yields, one well with which I am familiar having dropped from 250 to 30 gal. a minute as soon as the reserve

supply was exhausted. Many apparent variations from the normal are explainable by the influence of factors at some distance from the well. Thus a well sunk on a bare rock surface may sometimes yield much more than the quantity indicated in the table, for the reason that adjoining areas, from which a part of the supply comes, may have a cover or feeder of some thickness.

Ordinarily wells more than 500 ft. apart will not interfere appreciably with one another. Wells 200 ft. apart commonly yield not less than two thirds the sum of the normal individual yields. Sometimes wells located only a few feet from one another are entirely independent as to supplies.

The average reported yield for all wells in granitic rocks in Connecticut was about 15 gal. per minute, but many of the wells were less than 100 ft. in depth, and few were pumped to their full capacities. It seems likely that 20 to 25 gal. a minute is more nearly their actual average capacity. Probably not more than 1 in 50 of the wells fails to obtain water. The conditions in similar rocks in other parts of New England are essentially the same.

At a number of localities in New England granites have been utilized as a source of public supplies for small villages, but the limitations of the area tributary to any well or group of wells will prevent the use of such rocks as sources of supply for towns of any size.

AVAILABLE GROUND WATERS IN QUARTZITES.

A quartzite may be defined as a siliceous or quartz sandstone in which the original pore spaces have been filled with a silica cement, forming a dense, hard, compact rock even more nonabsorbent than granite.

It is, however, a rock which is generally more or less broken by joints or seams similar in character to those of granitic rocks and likewise characterized by the presence of considerable water.

Nowhere in this country are rocks of this class of any considerable importance as water producers, although many farm wells draw moderate supplies from the quartzites in Minnesota and elsewhere. That they are not more extensively utilized is due, in

a large measure, to the presence of overlying sands, gravels, or glacial drifts which will yield more copious supplies. Their great hardness, also, makes drilling both slow and expensive.

It is probable that, on the whole, jointing is fully as well developed in quartzites as in granitic rocks, and that, under similar conditions, they will yield quite as much water as the latter. Except, however, for villages and very small towns, we should not look to quartzites as sources of public supplies.

AVAILABLE GROUND WATERS IN SLATES AND SHALES.

Slate forms the country rock beneath the greater part of southern Maine, and is found in smaller isolated areas in the other New England states. Of these local slate areas, that underlying Boston may be mentioned. Owing to the scanty population and the abundance of water in the surface deposits over the greater part of the slate areas, only a moderate amount of drilling has been done. My associate, Mr. Frederick G. Clapp, however, has collected data from more than 200 wells in Maine in connection with work for the United States Geological Survey,* while I have myself collected the records of a considerable proportion of the deep Boston wells. The information regarding the waters of horizontal shales was collected by myself and assistants in Minnesota, Ohio, and elsewhere.†

Controlling Factors. — Slates and shales normally contain in their pores about 4 per cent., or 1.2 quarts of water per cu. ft., or four times as much as granite. This is equivalent to about 70 000 000 gal. within a radius of 500 ft. from a 300-ft. well, but, as in the granitic rocks and limestones, none of it is available to wells.

There are marked differences in the manner of occurrence of water in slate and in shale, for which reason it is necessary to bear in mind the differences in the two rocks. Shale is a soft, fine-grained rock resulting from the consolidation of clay, and

* Occurrence and Composition of Well Waters in the Slates of Maine. United States Geological Survey, Water Supply Paper 258, pp. 32–39, 1911.

† Geology and Underground Waters of Southern Minnesota. United States Geological Survey, Water Supply Paper 256, 1912. Underground Waters in Southwestern Ohio. United States Geological Survey, Water Supply Paper 259, 1912.

tending to split into thin plates parallel to the bedding or stratification. There is very little true shale in New England, but it is a very important rock west of the Alleghanies. Its beds are generally horizontal or moderately inclined, rarely on edge.

Slate is a harder and denser rock than shale. In most cases, the original bedding planes have been sealed, but it generally has a strong tendency to split along vertical or highly inclined planes as shown in Plate XII. These parting planes are due to pressure instead of to stratification, and are known as cleavage planes.

The waters of shales occur both in joints and in the bedding or lamination planes. The joints are fewer in number than in granitic rocks, but are, perhaps, somewhat more open, although well records do not indicate that they are water-bearing to any greater extent than those of granites. The lamination planes vary from a fraction of an inch to a foot or more apart, but, being horizontal, the weight of the overlying rock tends to keep most of them tightly closed. Comparatively few are water-bearing.

In *slates*, the jointing is much more strongly developed than in shales, the number of the seams often even exceeding those in granitic rocks and carrying correspondingly greater quantities of water. In addition there is often an equal or even greater quantity stored within the cleavage planes, for, being vertical or highly inclined, the latter are less affected, at least at moderate depths, by the weight of the overlying strata than are the bedding planes of the shales. They have a greater tendency, therefore, to remain open and afford passages for the downward percolating waters.

On the whole, it seems probable that the slates contain several if not many times the quantities of water held by equal bulks of granitic rocks. Neverthless, since the lateral extent of the joint and cleavage planes has been shown by the behavior of adjacent wells and wells near the margin of the sea to be even less than of those in granitic rocks (Table 4, page 247), it is certain that no well could be supplied for long from the waters stored within the rock. The water must, therefore, be derived mainly from the cover or feeder of overlying material. The part played by such feeders has already been discussed (page 246).

Cleavage in Slate. (Photo. by U. S. Geol. Surv.) The Presence of Cleavage Planes Materially Aids the Transmission of Ground Waters and Increases the Yield of Wells.

YIELD OF WELLS IN SLATES AND SHALES. — The comparative estimated yields of slates and shales under different conditions are shown in the following table.

TABLE 5.

ESTIMATED YIELD OF WELLS IN SLATES AND SHALES IN GALLONS PER MINUTE.

Thin Cover to Rock.

(Less than 10 feet.)

Depth of Well. (Feet.)	Diameter of Well. (Inches.)	Horizontal Shales. (Jointing Poorly Developed.)			Inclined Slates. (Jointing Well Developed.)			Calcareous Shales or Slates. (Containing Soluble Layers.)
		Slopes or Sharp Hills.	Plateaus or Upland Plains	Valleys.	Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.	
100–200	4	1½	3	5	6	9	12	Variable, according to whether or not the well encounters solution passages. Average 25 to 50 per cent. more than non-calcareous slates.
,,	6	2	4	6	8	12	14	
,,	8	2½	5	8	10	14	16	

TABLE 6.

Thick Cover to Rock.

(More than 50 feet.)

Depth of Well. (Feet.)	Diameter of Well. (Inches.)	Horizontal Shales. (Jointing Poorly Developed.)			Inclined Slates. (Jointing Well Developed.)			Calcareous Shales or Slates. (Containing Soluble Layers.)
		Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.	Slopes or Sharp Hills.	Plateaus or Upland Plains.	Valleys.	
100–200	4	4	6	10	20	25	30	Variable, acording to whether or not the well encounters solution passages. Average 25 to 50 per cent. more than non-calcareous slates.
,,	6	5	8	12	25	30	40	
,,	8	6	10	15	30	40	50	

The above estimates of approximate yields are subject to the same limitations and qualifications as those given for the granitic rocks on page 247.

It is to be noted that the yield of horizontal shales where the covering is thin is very small. This is due largely to the infrequency of joints, in the absence of which the waters find great difficulty in entering the rock, for the reason that the shale layers are themselves essentially impervious to the passage of water. Many wells on slopes are failures owing to free lateral drainage (Plate XIII). Even with thick covers or feeders, the supplies of horizontal shales are, for the reasons indicated, less than those of granitic rocks.

In the slates proper, on the other hand, the supplies usually average slightly higher than in the granites and similar rocks, especially in the deeper wells, for the reason that both joints and cleavage planes contribute to the yield.

In the calcareous slates and shales, or those containing considerable quantities of lime, solution passages are often dissolved along the limey layers. These passages are frequently half an inch or more in diameter and extend for long distances. When encountered by wells they often yield good supplies, although the ultimate yield is generally controlled by the rate of absorption from some more or less distant feeder.

Adjacent slate and shale wells are, perhaps, more likely to interfere with one another on pumping than are wells in the granitic rocks, but the effect of the interference is commonly less serious. Usually, wells over 200 ft. apart will give at least three fourths of the sum of their normal individual yields.

The percentage of unsuccessful shale wells on slopes is, when the covering is thin, quite high, probably 1 in 5 failing to get even enough for family use. With thick coverings, the number of failures is probably not more than 1 in 10. With inclined slates and the calcareous varieties of slate and shale the number of failures is probably about the same as in granite, or about 1 in 50. When sunk close to salt water, the percentage of failures is considerable, and indicates that it is undesirable to drill within 500 ft. of the shore.

SEEPAGE FROM STREAM BANK. (PHOTO. BY U. S. GEOL. SURV.) ILLUSTRATING MANNER OF DRAINAGE OF ROCKS AND SOILS ON OR NEAR SLOPES.

AVAILABLE GROUND WATERS IN LIMESTONES.

Limestones, including the crystalline varieties known as marbles, are found principally in northern Maine and in a more or less interrupted belt along the western edge of Vermont, Massachusetts, and Connecticut, although small areas occur elsewhere in New England. In the Mississippi and Ohio valleys and at many other points in the West and South there are formations of great importance.

Controlling Factors. — Limestones have an average porosity of about 5 per cent. and will hold about 1.5 quarts of water per cu. ft., or some 88 000 000 gal. within a radius of 500 ft. of a 300-ft. well, but, as in slates and granites, this is so strongly held by the force of capillarity that practically none of it is available to wells.

The available supplies from limestones come, in nearly every case, from solution passages. These are dissolved by percolating waters wherever there is an opportunity for circulation, generally along some fault (Plate XIV, Fig. 1), joint, or bedding plane, especially at the contact with some shaley or other impervious layer. At first the openings are very small, usually only a fraction of an inch in diameter, but there is a general tendency for the water movement to become concentrated along certain lines, with the result that tubular passages, varying from a few inches to many feet in diameter, are eventually formed. The smaller passages often form a ramifying network along bedding planes, as shown in Plate XIV, Fig. 2.

The largest passages are usually formed at or above drainage level, that is, above the level of the valleys into which the limestone waters drain. Our well-known caves, such as Mammoth, Wyandotte, etc., are examples of this type. At great depths the circulation of water is less rapid and the passages are smaller. Nevertheless, as indicated by water-worn specimens brought up in drilling, passages a foot or more in diameter occur at depths of more than 1 000 ft.

The length of the larger passages is often considerable. One passage in the Mammoth Cave of Kentucky is nearly 5 miles in length, while certain surface features, such as great sinks, indicate that passages of several, if not many, times this length may occur.

The water supplies of limestones, unlike those of most other classes of rocks, are not solely, and possibly not even chiefly, dependent on the presence of overlying soil or other feeders. A large quantity of water, on the contrary, passes downward through sinks or basin-like depressions connecting with the underground passages. Through these, the surface waters enter the rock directly and without filtration. Whole streams, sometimes flowing millions of gallons a day, sometimes disappear into cavernous passages in the limestone.

From the preceding it will be apparent that the free water in limestones will far exceed that of the granitic rocks and the slates and shales, and will often, as a matter of fact, be sufficient to supply a well indefinitely without the aid of the usual feeder.

The ramifying networks of small passages, previously mentioned and illustrated (Plate XIV, Fig. 2), are more dependable sources of supply than are the large passages, since they are generally of considerable lateral extent as compared with the tubular passages. A well may miss the latter entirely, even though there may be several in its immediate vicinity, but it will rarely fail to encounter at least one of the broader bedding planes. The supplies of the latter, however, are usually more limited than those of the big passages.

Topography is a far more important factor in determining the yield of limestone wells than of those of any other class of rock. The reason for this is the open character of the water-bearing passages, which commonly permit the limestone waters to freely drain into the adjacent valleys, thus preventing the accumulation of reserve supplies. Large permanent supplies are seldom found above drainage or valley level, except where large streams of moving water are encountered. Often it will not be the valley nearest to the well that will determine the drainage level, but rather some distant valley into which the underground stream eventually discharges.

It is to be borne in mind that whenever limestone wells are considered as a source of public supplies, there is always considerable danger of contamination, owing to the entrance of much of the water into the ground through sinks and without filtration.

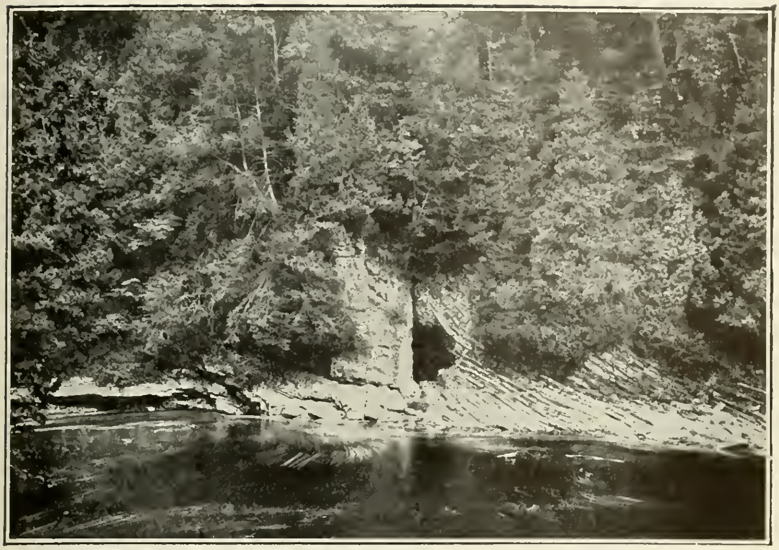


FIG. 1.

WATER PASSAGE ON FAULT-PLANE IN LIMESTONE. (PHOTO. BY U. S. GEOL. SURV.) SUCH PASSAGES OFTEN AFFORD LARGE QUANTITIES OF WATER TO WELLS.

FIG. 2.

NETWORK OF SOLUTION PASSAGES ALONG BEDDING PLANES IN LIMESTONE. (PHOTO BY U. S. GEOL. SURV.) THESE SMALL ($\frac{1}{2}$-INCH) PASSAGES EXTEND IN A RAMIFYING NETWORK OVER AREAS AND YIELD MUCH WATER TO WELLS.

Such waters must always be carefully watched for any sudden increase in chlorine or the appearance of bacilli coli.

YIELD OF WELLS IN LIMESTONE. — Too few wells have been sunk in the limestones of New England to warrant any broad conclusions, but I have had the opportunity, in connection with investigations for the United States Geological Survey in Ohio and Minnesota, to study the yield of limestones under a wide range of conditions. From these investigations* it appears clear that the yield of limestones, except where very near the edge of a valley into which their waters may drain, will average not less than 50 per cent. greater than those from slates and shales, as set forth in the tables on page 251. The maximum possible yield of limestone wells is many times that of wells in the latter rocks.

Compared with sandstones, on the other hand, the average yield of wells in limestone is comparatively small, although individual wells encountering large solution passages may run as high or higher than the largest sandstone well. In southeastern Minnesota practically every one of the scores of public supplies derived from rock wells obtains its water from sandstone, although limestone is equally and often even more convenient of access and its water equally good from the chemical and sanitary standpoint.

The average yield of a limestone well under unfavorable conditions, as on slopes with thin coverings, is probably about 25 per cent. less than that of a sandstone well in the same situation. Below drainage level and beneath thick coverings, the average yield of limestone wells is estimated to be 50 per cent. to 75 per cent. less than wells in sandstone.

It is not considered advisable, owing to the excessively wide variations of individual wells, to attempt to show the probable average yield of limestone wells by means of a table. The foregoing comparisons will, however, afford a fair idea of the quantities to be expected from wells of this class. It may be said that, in general, limestones will afford ample water for domestic and farm purposes, and, when beneath drainage level, will ordinarily

* Geology and Underground Waters of Southern Minnesota. United States Geological Survey, Water Supply Paper 256, 1912.

Underground Waters in Southwestern Ohio. United States Geological Survey, Water Supply Paper 259, 1912.

furnish sufficient quantities to supply small villages and occasionally large villages and even towns of considerable size. The yield of limestone wells is not usually materially affected by their diameters, except insofar as the size may limit the capacity of the pumps used.

AVAILABLE GROUND WATERS IN SANDSTONES.

The sandstones of New England are mostly found in the Connecticut Valley lowlands of Massachusetts and Connecticut, where they underlie the river and the broad, flat terraces, several miles in width, which border the stream on both sides. They are known as the "red-rocks" from the prevailing reddish or brownish color. Other local areas of sandstone, largely of a grayish type, are found at a number of points.

The sources of information concerning the waters of the sandstones of New England are the investigations for the United States Geological Survey by H. E. Gregory, W. H. C. Pynchon, and the writer, while the data from other parts of the country are drawn from the Survey reports on southwestern Ohio, southern Minnesota, and the states on the east flanks of the Rocky Mountains.*

CONTROLLING FACTORS. — The greater part of the water in sandstone occurs, as in most other rocks, in the pore spaces between the grains, but unlike the rocks previously considered, these pore spaces are large, mostly supercapillary, and usually give up the greater portion of their supply to wells.

Most sandstones are composed of mixtures of coarse and fine grains, which are bound together by cements of lime, silica, or

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* Underground Water Resources of Connecticut. H. E. Gregory, United States Geological Survey, Water Supply Paper 232, pp. 105–138, 1909.

Drilled Wells of the Connecticut Valley. W. H. C. Pynchon, United States Geological Survey, Water Supply Paper 110, pp. 65–74, 1905.

Triassic Rocks of the Connecticut Valley as a Source of Water Supply. M. L. Fuller, United States Geological Survey, Water Supply Paper 110, pp. 95–112, 1905.

Geology and Underground Waters of Southern Minnesota. C. W. Hall, O. E. Meinzer, and M. L. Fuller, United States Geological Survey, Water Supply Paper 258, 1911.

Underground Waters of Southwestern Ohio. M. L. Fuller and F. G. Clapp, United States Geological Survey, Water Supply Paper 259, 1912.

The High Plains and their Utilization. Willard D. Johnson, United States Geological Survey, 21st Annual Report, part 4, pp. 601–674, 1900; 22d Annual Report, part 4, pp. 631–669, 1901.

Also numerous papers by N. H. Darton, G. K. Gilbert, and Erasmus Haworth. (See bibliography of Geological Survey publications on ground waters, Water Supply Paper 120, 1905.)

iron. The extent to which these cements have filled the original pores and thus partially closed the intercommunicating passages between the pore spaces regulates, to a large degree, the freedom of movement of the water within the rock, and largely determines the yield to wells. Inasmuch as the cementing is naturally more complete where the grains and pores are small, it follows that

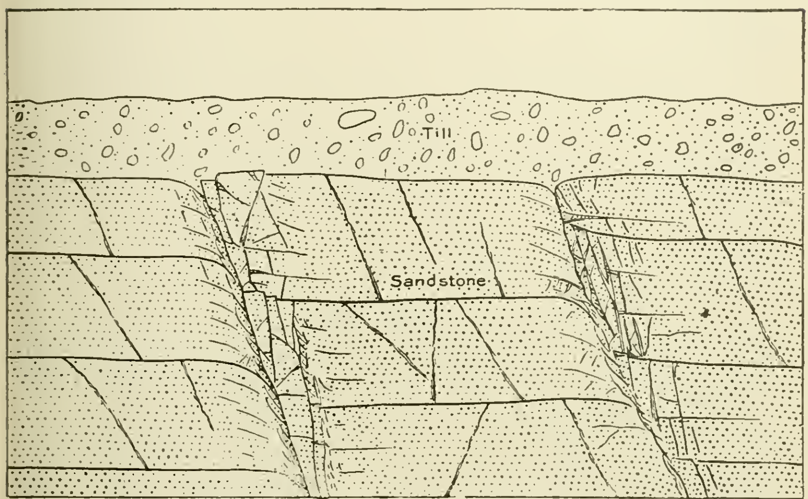


Fig. 2.

Diagram Showing Crushed Zones along Faults in the Sandstones of the Connecticut Valley, with Overlying Feeder of Till. (H. E. Gregory.)

the presence of fine material, especially silt, in sandstone is an important factor in determining yield.

In the finer and more silty sandstones which have, let us say, an average porosity of 5 per cent., only about one fifth will be yielded to wells, while four fifths of the water will remain permanently in the rock. In the more coarse and open varieties, whose porosity is sometimes as high as 25 per cent., about three fifths will be yielded to wells and only two fifths remain behind. In the first instance the yield will be equivalent to 0.3 quarts to each cubit foot of sandstone; in the second, to 4.5 quarts.

The yield of a rock holding the latter quantity, if it is of any considerable thickness, is enormous. With a bed only 10 ft. thick there would be stored in a single acre 490 000 gal. Since a well in sandstone may draw from scores if not hundreds or even thousands of acres, the possibilities of obtaining large supplies for public purposes are usually very good.

Although a sandstone bed is usually more or less saturated throughout, the movement of the water, owing to the compactness of grain, may be comparatively slow and the direct yield to a well somewhat limited. Usually, however, there are more or less well-defined bedding planes in the rock, and to these the waters are delivered from the pores over considerable areas. A well encountering such a bedding plane will obtain far more water than it would otherwise secure. There is also a strong tendency toward concentration of movement within the rock along beds or layers of shale.

Joint planes play a far less important part in determining the water-bearing capacity of a sandstone than in the crystalline rocks and slates. Nevertheless, they sometimes afford passages for large quantities of water. This is especially true where there has been faulting along the joint planes and the rock has been more or less crushed and broken, as shown in Fig. 2, which is a section of the sandstone in the Connecticut Valley. The

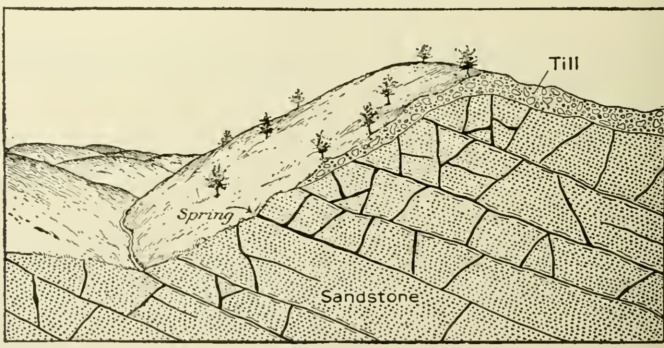


FIG. 3.

DIAGRAM SHOWING DRAINAGE OF SANDSTONE SLOPES BY SPRINGS. (H. E. GREGORY.)

exceptional yield of certain wells at Hartford, Conn., which is from three to five times that of the usual well in similar rocks in the vicinity, is attributed to such a crushed zone.

The action of the soils or other feeders overlying the outcrops is much the same as in other rocks, but since the sandstones are themselves absorbent, the presence of feeders is not so vital.

Topography has a strong influence on the yield of sandstone wells. It is not so much, however, that the rainfall is quickly shed from the slopes as it is that the sloping surfaces cutting the sandstone beds permit the easy escape of their waters (Fig. 3).

Yield of Wells in Sandstone. — The average estimated yield of wells in sandstones of different types and under varying conditions of topography and depth are given in the following table.

TABLE 7.

Estimated Yield of Wells in Sandstones.

(In Gallons per Minute.)

Diam. of Well. (Inches.)	Fine to Medium Grained and Silty Sandstones.				Coarse or Open Sandstone.			
	Depths 100 to 300 Feet.			Deep Wells.	Depths 100 to 300 Feet.			Deep Wells.
	Slopes.	Upland Plains.	Valleys.		Slopes.	Upland Plains.	Valleys.	
4	15	30	40	45	20	100	125	150
6	20*	40*	60*	70	25	150	200	350
8	25	50	70	85	30	200	250	500
10	30	60	80	100	35	250	300	600

As in other rocks, individual wells in sandstone vary greatly from the average yields according to local conditions. Practically no well in sandstone, however, unless near the immediate edge of a sharp drop, will fail to get some water, and under favorable conditions the supply may reach 1 000 gal. a minute or more, or upwards of a million and a quarter gallons per day.

* Actual averages computed for ninety wells in Connecticut are 17, 43, and 64 gal. per minute respectively for slope, upland plain, and valley wells. (H. E. Gregory, United States Geological Survey, Water Supply Paper 232, p. 137, 1909.)

The diameter of the well is of more importance in drilling in sandstone than in most other rocks for the reason that water enters from every point on the sides and any increase of exposed area tends to increase the rapidity of entrance of the supply. The effect is greatest in the silty sandstones. In the very open varieties the diameter is less important, as the water is often able to enter as fast as required by the pumps regardless of diameter. Large diameters are of advantage through the increased size of pumps that may be used.

The small yield of wells of moderate depths (100 to 300 ft.) situated on slopes is due to the fact that, while the bottom of the well may be below drainage, the head of the water, which determines its rate of entrance, is relatively low, owing to the drainage of the supplies from the upper rocks. Under hills and upland plains this leakage is not so important, and the yield of wells is noticeably higher. Under broad plains the quantity afforded by a well approaches that given by one in the valley. Deep wells, under which head may be included those from 300 to 1 000 ft. or more in depth having not less than four fifths of their depth below drainage level, give still larger supplies.

The yields of the table are for sandstones of the ordinary types. The dense hard varieties, such as occur in the vicinity of Boston, in Narragansett Bay region, etc., often approach quartzites in character. In such rocks the water supplies are determined by the jointing, and vary but little in quantity from those secured from quartzites and granites.

Owing to the open character of the rock, adjacent wells in sandstone almost always interfere with one another if the withdrawal is in excess of the inflow from other parts of the rock. The yield of nearby wells may be less than 50 per cent. of the sum of their yields when pumped separately, but one well seldom robs the entire supply of its neighbors, as is sometimes the case in granite, shale, and quartzite wells. When the water-bearing sandstone is of considerable thickness and the replenishment rapid, the wells may often be pumped to their full capacity without serious interference.

The sandstones of the Connecticut Valley are medium grained and somewhat silty. Their average quantitative possibilities as

sources of public supply are fairly well shown by the table, although locally the supplies will run much higher. Their mineralization must, however, be carefully considered in connection with any project for their development.

In the West, the Dakota and other sandstones furnish water for scores if not hundreds of villages and towns, the consumption of some of which reaches several million gallons per day. Over broad areas these sandstones are unfailing sources of supply where the demand does not exceed one or two million gallons a day.

AVAILABLE GROUND WATERS IN CONGLOMERATES.

Conglomerates are consolidated gravels. They consist of pebbles of various sizes, the spaces between which were originally filled with sand or silt which has since hardened into a more or less firm bond. Since in all deposits of mixed materials the finer particles control the water movements, the conglomerates are usually to be classed with sandstones as regards their water-bearing capacities. The table of yields of wells in the latter is, in a general way, applicable to the conglomerates, although it is probable that, on the whole, the average yields of the conglomerate wells are slightly (15 to 20 per cent.) less than those in sandstones, for the reason that the porosities of the former are usually somewhat less than those of the latter, while they are also likely to be somewhat more silty.

In some localities the conglomerates have been so firmly cemented and the pores so completely filled with mineral matter that they have become hard, dense, and non-absorptive. The Boston conglomerates are typical examples of this class. In such cases the available water will be found largely, if not entirely, in the joint or similar seams, and the supplies will be essentially the same as indicated in the table for wells in granitic rocks.

AVAILABLE GROUND WATERS IN CLAYS.

Clays are of extended occurrence in New England, underlying the sandy surface alluvium of many of our river valleys and other depressions, as well as forming the foundation upon which rest certain of our broad sandy plains such as those of Cape Cod.

Clays also underlie the surface deposits throughout a large part of southern Maine and considerable areas of the Champlain valley of Vermont.

Controlling Factors. — As indicated in the table on page 238, clays are among the most porous of any of our natural deposits, ranging from 40 to 70 per cent., with a probable average of about 50 per cent. Those who have noted the network of great shrinkage cracks checking the surface of a dried mud flat, will appreciate how much of the original volume must have been water.

The water held in the pores of clays amounts to 3.75 gal. per cu. ft., or 880 000 000 gal. within a radius of 500 ft. of a 300-ft. well. The storage within the limits indicated would, if available, supply 1 000 000 gal. daily for a period of more than two years. Practically none of this, however, is directly available to wells, at least to those in the purer varieties free from sand. This is due in part to the tenacity with which the water is held by capillarity, and in part to the fact that it is practically impossible to keep clay from entering a well with the water in sufficient quantities to prevent its utilization. Anything that will shut out the clay, so that the water will enter free from turbidity, will prevent the entrance of the supply with sufficient rapidity to be of practical value.

Clay, although not in itself an important producer of water supplies, is often of great value as a feeder. Its effect on the yield of the Boston wells has already been pointed out. That it yields clear water to underlying formations while affording turbid water to wells is due to the fact that in the former case the water seeps from broad areas with exceeding slowness, while in the latter, under ordinary conditions of pumping, the velocity of entrance of the water is such that the clay particles are carried along with it.

Yield of Wells in Clays. — Wells in pure clays yield practically nothing under prevailing conditions of pumping. In many clays, however, there are interbedded streaks or strata of sand which sometimes yield considerable quantities of water, although seldom enough for public supplies. It is not practicable to tabulate the yield of clay wells, but it may be said that, in general,

where any water at all is obtained the volume will not vary greatly from those indicated for horizontal shales (page 251).

AVAILABLE GROUND WATERS IN GLACIAL TILL.

Till is the geological term for the heterogeneous unstratified materials left by the glaciers formerly covering the northern half of this continent. In this vicinity it is a mixture of clay and bowlders with some sand, and is often known as bowlder-clay, It is the material of which Beacon Hill and most of the other hills around Boston and in the harbor are composed, as well as hundreds of similar hills in other parts of New England. Other and often more sandy varieties form the general sheet of glacial drift mantling the uplands throughout most of the New England states.

Controlling Factors. — The clayey varieties of till are similar in porosity and water-holding capacity to the clays, and likewise hold tenaciously to their supplies. In the more sandy and gravelly types, on the other hand, the conditions of storage, movement, and delivery to wells are more like those in true sands and gravels. All tills, however, are likely to be characterized by great variations in composition and texture within short distances, as are also the intercalated layers of sand or gravel. The area drawn upon is, therefore, likely to be more restricted than in the relatively uniform and continuous stratified deposits.

In New England, much of the till occurs in hills or as a comparatively thin mantle over rock uplands and in situations topographically unsuited to the development of large supplies. Locally, however, there are thick deposits in the valleys, many of which are sandy and porous. In Ohio, Indiana, Michigan, and other parts of the central United States, the till forms a somewhat uniform sheet, often several hundred or even a thousand feet or more in thickness. This great accumulation practically always contains sandy or gravelly beds of considerable thickness.

Yield of Wells in Tills. — The yield of till wells varies according to the predominance of clay or sand, and to the presence of sand or gravel layers. The more clayey varieties usually yield very little water, while the sandy types sometimes afford supplies approaching those of true sands and gravels. The estimated average yield is indicated in the following table.

TABLE 8.

ESTIMATED YIELD OF WELLS IN TILL.
(In Gallons per Minute.)

Depth of Well. (Feet.)	Diam. of Well. (Inches.)	Clayey Tills.			Sandy Tills.		
		Slopes.	Upland Plains.	Valleys.	Slopes.	Upland Plains.	Valleys.
100–200	4	4	6	10	15	30	50
,,	6	5	8	12	20	40	80
,,	8	6	10	15	25	50	100

The usual qualifications, already indicated for wells in other materials, apply to till wells. The yields for "sandy types" are for moderately sandy varieties. More porous varieties will approach sandstones or even pure sands in yield.

The diameter of the well in the finer tills is a factor of much importance. Where it is found to be impossible to obtain the needed supply from the ordinary driven or drilled well, a large open well, often from 25 to 75 ft. in diameter, is sometimes successfully used for the development of public supplies.

In general, where the till is of considerable thickness, and not too clayey, it will yield enough water for a small village, but unless sandy or containing sand or gravel layers of some thickness, the yield is seldom sufficient for the larger towns or cities.

AVAILABLE GROUND WATERS IN SANDS AND GRAVELS.

Sands and gravels are of such general distribution in New England that the enumeration of their areas is unnecessary. The greatest single sandy area is in southeastern Massachusetts, comprising Cape Cod and a large part of Plymouth County. The scattered areas are chiefly in river valleys or in broad basins between rock or till uplands. Outside of New England, the chief sandy formations are along the Atlantic coastal plain, the waters of which I described some years ago in a paper in the proceedings of the American Water Works Association.* Extensive sandy

* Proc. Am. W. W. Association, 1908, p. 292.

deposits also underlie the lower Mississippi Valley, while sandy drift, similar to that of New England, occurs throughout the glaciated area of the northern United States and Canada.

Controlling Factors. — The water-bearing capacities of sands and gravels are largely a factor of their porosities. Where the grains are all of the same size, the porosity is independent of their diameter. For instance, the large number of small pores in a sand are equivalent in volume to the comparatively small number of large pore spaces in a gravel. When, however, small grains fill the spaces between larger ones, as sand grains between the pebbles of a gravel, the porosities are much reduced.

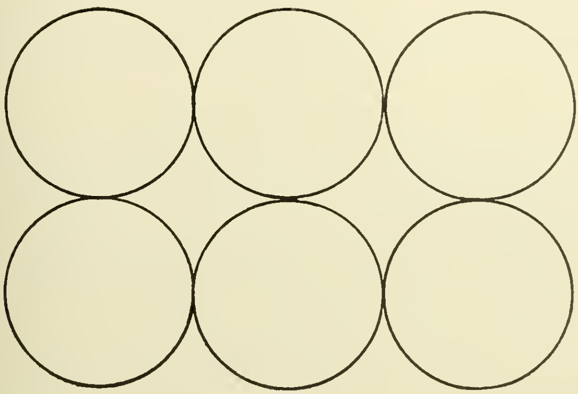


Fig. 4.

Arrangement of Spherical Pebbles to Give Maximum Porosity of 47.6 Per Cent.

Although the size of grains in uniform sands or gravels does not affect the porosities, their arrangement is of great importance. When arranged in the loosest possible manner (Fig. 4), they have a porosity of 47.6 per cent.; where arranged in the most compact manner (Fig. 5), the porosity is only 26 per cent. The actual porosities in nature are usually about midway between the two.

In laboratory tests, the porosities of uniform sands and gravels are found to be about 35 per cent., and of mixed pebbles and sand, which is the ordinary condition of our gravels, about 30 per cent.

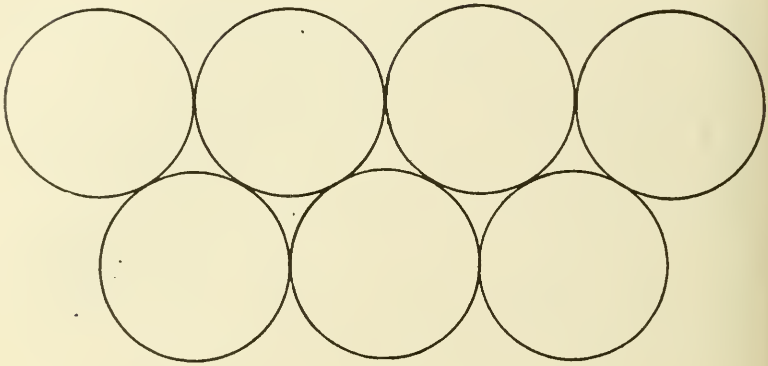


FIG. 5.

ARRANGEMENT OF SPHERICAL PEBBLES TO GIVE MINIMUM POROSITY OF 25.9 PER CENT.

(Fig. 6). In nature the materials are subject to pressure, due to the weight of the overlying deposits, equal to about 1 lb. per sq. in. for every foot in depth. This pressure produces a compacting, according to laboratory experiments with pressures of from 0 to 100 lb. per sq. in. made under my direction by

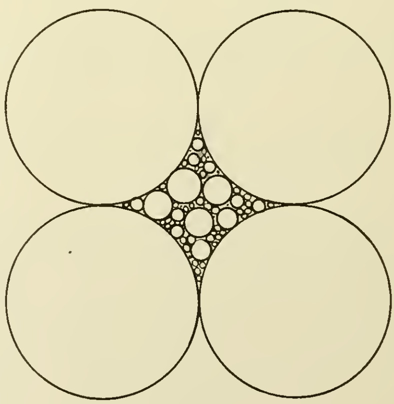


FIG. 6.

ARRANGEMENT OF SPHERICAL PEBBLES AND GRAINS OF DIFFERENT SIZES, GIVING VARIABLE POROSITIES, USUALLY FROM 20 TO 30 PER CENT.

Mr. L. C. Cheminant in connection with some recent investigations for the city of San Francisco, of from 5 to 8 per cent., reducing the actual probable porosity in the ground by an equivalent amount.

When water is withdrawn from a sand or gravel, a certain quantity remains behind as residual moisture, and is not yielded to wells. The quantity thus withheld varies with the size of the grain from 5 per cent. in the gravels to perhaps 20 per cent. in the finer sands or those approaching silts in texture. It still further reduces the effective porosities or available storage. The reductions due to compression and residual moisture are shown in the following table. The last column shows the quantities of water actually available.

TABLE 9.
Effect of Porosity Deductions.
(Per Cent. of Volume.)

Material.	Porosities of Loose Materials. (Laboratory Tests.) Per Cent.	Loss of Porosity Due to Weight of Overlying Material. Per Cent.	Loss Due to Water Remaining in Pores. (Residual Moisture.) Per Cent.	Effective or Available Porosity. Per Cent.
Gravel (mixed sand and pebbles) . .	20–30	5–8	4–8	10–20
Sand (medium to coarse)	30–40	4–6	6–10	15–25
Sand (fine and very fine)	30–40	0–5	10–25	5–20

The quantity of water stored in the sands and gravels is not the only thing that must be considered. The real determining factor in a permanent supply is the rate of replenishment. In an inclosed basin or other area not receiving outside supplies, replenishment is mainly from the rainfall. The whole rainfall is, of course, not available, large deductions being necessary for evaporation and surface run-off.

Underflow Measurements. — In sand and gravel deposits receiving contributions from outside their own areas, as is the case of most of the formations in stream valleys, a determination

of the rate of underflow is necessary to fix the quantity of accessions from sources other than rainfall. When replenishment occurs from a stream flowing over the surface of the deposits being drawn upon, a still further determination, that of downward percolation, is necessary.

A fairly exact determination of the rate and volume of underflow can be made by actual measurement by the electrical method devised by Prof. Charles S. Slichter, of the University of Wisconsin

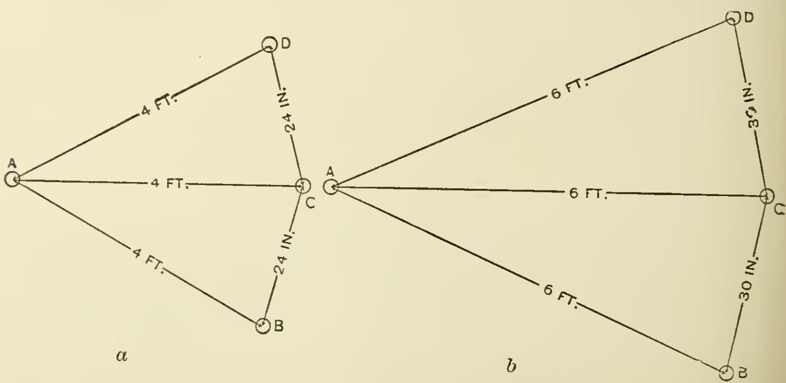


Fig. 7.

Arrangement of Wells in Underflow Tests. (C. S. Slichter.)

and the United States Geological Survey. In brief, the method consists in sinking four 2-in. wells in the form of a fan or triangle, as indicated in Fig. 7, the apex of the system being toward the supposed direction from which the water is moving. Common salt or ammonium chloride is inserted in the apex well and the time required for penetration into the other wells taken by electrical recording apparatus or determined from water samples taken and tested at short intervals. A view, showing the apparatus in use, is given as Plate XV, Fig. 2. Detailed accounts of the method and its applications are given in Water Supply Paper 110 of the United States Geological Survey, pages 17 to 31, and in other Survey publications.

The rate of percolation from streams is best determined by the Slichter method used in conjunction with a pumping test.

FIG. 1.

COMMON ARRANGEMENT OF GRAINS IN SANDS, SHOWING LOOSE PACKING ORDINARILY PREVAILING. ENLARGEMENT 40 DIAMETERS. (ILLUS. FROM ROCK PRODUCTS.)

FIG. 2.

VIEW OF WELLS, WIRING, AND RECORDER IN UNDERFLOW TESTS. (PHOTO. BY U. S. GEOL. SURV.)

Where a direct test is not made, it is possible to form an approximate idea of the rate and volume of underflow by computations based on temperature, size of grain, porosity, head, etc. Space is not available to go into this question in the present paper, and the reader is referred to the report by Professor Slichter published by the United States Geological Survey as Water Supply Paper 67 (pages 24–30), in which formulas and tables for use in estimating underflows are to be found. Other valuable discussions of the movements of water in sands are to be found in the reports of Allen Hazen and Prof. F. H. King.* It may be stated that size of grain and temperature are factors of the greatest importance. The flow through a sand whose effective size of grain is 1 mm. or about $\frac{1}{25}$ in., which may be regarded as a fairly coarse sand, is 10 000 times that through a clay whose particles have an effective size of .01 mm. The flow at 70 degrees is about double that at 32 degrees. Again, the movement of water through sands of the same size of grains varies with the nature of the packing, a sand with a 40 per cent. pore space having a movement of 2.6 times that through one of similar grain but with packing giving a 30 per cent. porosity.

Something of the actual rates of underflow movements under ordinary conditions is indicated by the following table.

TABLE 10.

COMMON RATES OF UNDERFLOW.

(After C. S. Slichter.)

(Gradient or Head, 10 ft. per Mile; Porosity, 32 Per Cent.; Temperature, 50° F.)

Material.	Diameter of Grain in Millimeters	Movement in Miles per Year.	Movement in Feet per Year.	Movement in Feet per Day.
Fine sand	0.2	0.01	52.8	0.145
Medium sand	0.4	0.04	216.0	0.6
Coarse sand	0.8	0.16	845.0	2.3
Fine gravel	2.0	1.02	5 386.0	14.76

* Some Physical Properties of Sands and Gravels. Allen Hazen, Report of Massachusetts State Board of Health, 1892, p. 541. Principles and Conditions of the Movements of Ground Water. F. H. King, 59th Annual Report, United States Geological Survey, part 2, p. 59, 1899.

YIELD OF ISOLATED AREAS OF SANDS AND GRAVELS. — The yield of wells in isolated areas is dependent upon the inter-relation of rainfall, evaporation, and run-off. Estimates of the quantities afforded under conditions prevailing in New England are given in the following table, in which part of the figures are the estimates of the New York Commission on Additional Water Supply, based on extended and detailed studies on Long Island in 1903.

TABLE 11.

YIELD OF ISOLATED AREAS OF SANDS AND GRAVELS.

Rainfall. (Inches.)	Estimated Evaporation. (Inches.)	Estimated Run-off as Flood Flow. (Inches.)	Estimated Ground-water Increment. (Inches.)	Yield per Acre per Day. (Gallons.)	Acre Yield per Minute per Ten-hour Day. (Gallons.)
35*	17*	3*	15 *	1 116	1.85
$37\frac{1}{2}$	17	4	$16\frac{1}{2}$	2 228	2.03
40	17	5	18	1 339	2.23
$42\frac{1}{2}$*	17*	6*	$19\frac{1}{2}$*	1 451	2.41
45	17	7	21	1 562	2.60

The foregoing table shows the limitations of yield where there are no ground water additions from outside sources. Under such conditions the yield is essentially dependent upon area.

YIELD OF NON-ISOLATED AREAS OF SAND AND GRAVEL. — When additions from outside the area normally tributary to the wells occur, the supply is largely dependent upon the rate of underflow. The rate of movement in materials of different sizes has been indicated in the table on page 269. The following table shows the volumes that may be anticipated under varying conditions of porosity and movement.

The figures in the table show the underflows passing given points before pumping has begun. They are the quantities which will normally be available to wells without material readjustment of replenishment conditions.

After the pumps are started, the movement of the water will be greatly accelerated because of the increased gradient resulting from the local lowering of the water table near the well (see

* Report of New York Commission on Additional Water Supply. W. E. Spear, p. 829, 1903.

TABLE 12.

TRANSMISSION THROUGH SANDS AND GRAVELS.
(Per One Thousand Square Feet of Cross-section.)
Head, 10 ft. per Mile; Temperature, 50° F.

Materials.	Porosity. Per Cent.	Relative Flow.	Flow in Gallons per Minute.
Medium sand (Effective size, .4 mm.)	26	1.00	0.4
	28	1.28	0.5
	30	1.61	0.6
	32	1.99	0.8
	34	2.43	1.0
	36	2.93	1.2
Coarse sand (Effective size, .8 mm.)	26	1.00	1.6
	28	1.28	2.1
	30	1.61	2.6
	32	1.99	3.3
	34	2.43	4.0
	36	2.93	4.8
Fine gravel (Effective size, 2. mm.)	26	1.00	10.2
	28	1.28	13.1
	30	1.61	16.4
	32	1.99	20.5
	34	2.43	24.8
	36	2.93	30.0

Slichter, *loc. cit.*, for tables, etc.). Moreover, since a heavily pumped well intercepts and utilizes the underflow over a much greater cross section than 1 000 sq. ft., the supplies actually available at a given point will ordinarily be several if not many times the quantities indicated in the table. The amount and permanency of the supply that may be withdrawn in excess of the normal underflow will be regulated by the readiness with which replenishment by downward percolation from surface sources occurs. This, as previously indicated, is best determined by combined pumping and underflow tests.

UTILIZATION OF ACCUMULATED STORAGE. — The storage capacities of sands and gravels are very great, and in many instances, even though the wells may be drawing from them faster than the water is replenished, the supplies may be sufficient to make it possible to postpone for many years the installation of more

expensive systems, with their attendant increased cost of maintenance and higher interest charges. The following table shows the available supplies in materials of varying porosities after the necessary deductions for compacting and residual moisture have been made. The compacting and residual moisture factors are based on experiments made for the writer by L. B. Cheminant in the laboratories of the Department of Public Works of San Francisco in connection with ground-water investigations for that city.

TABLE 13.

STORAGE IN SANDS AND GRAVELS.

(Gallons per One Thousand Cubic Feet. Porosities are in per cent. of volume.)

Material.	Porosity by Laboratory Test. Per Cent.	Probable Porosity of Undisturbed Material. Per Cent.	Deductions for Residual Moisture. Per Cent.	Available Porosity or Storage Capacity. Per Cent.	Storage in Gallons per 1 000 Cubic Feet.
Very fine sand (approaching silt)	30	30	25	5	374
	30	30	20	10	748
	35	30	25	5	374
	35	30	20	10	748
	40	35	25	10	748
	40	35	20	15	1 122
Fine sand	30	30	15	15	1 122
	35	30	15	15	1 122
	40	35	10	20	1 496
Medium sand	30	30	10	20	1 496
	35	30	10	20	1 496
	40	35	10	25	1 870
Coarse sand	30	30	7	23	1 720
	35	30	7	23	1 720
	40	32	7	25	1 870
Gravel (mixed with sand)	20	16	6	10	748
	25	21	5	16	1 197
	30	25	5	20	1 496
	35	27	4	22	1 646

Applying the figures of the above table to a larger area, we find that a tract of sandy deposits one square mile in extent with

an average depth of saturation of 50 ft. and an available yield of 15 per cent. should afford about 1 568 000 000 gal., or enough to supply a million gallons a day for 1 568 days, or nearly 4½ years.

Since, even in deserts, there are practically always more or less additions to the ground-water reservoirs through replenishment from rainfall or percolation from temporary or permanent streams, the length of time the accumulated storage within the ground may be drawn upon by a water-works system will depend on the difference between such replenishment and the quantity withdrawn rather than on the absolute storage. Since this difference is often slight, at least as compared with the total volume of ground-water reserves, the probable life of a system under such conditions is often sufficient to warrant the installation of relatively expensive and permanent plants.

Sands and Gravels as Sources of Supplementary Supplies. — The utilization of sands and gravels as supplementary sources to eke out deficiencies of existing water supplies is often both practicable and desirable. This may be illustrated by the following hypothetical example, which, however, is probably fairly representative of conditions existing at many points.*

"Let it be assumed that a town of 20 000 people using 1 000 000 gal. daily has a reservoir holding sixty days' supply, or 60 000 000 gal., and that the inflow exceeds the consumption from December

TABLE 14.

Conditions without Wells.

Thirty Days Ending	Regular Supply.	Deficiency.	Amount Remaining in Reservoir.
May 31	30	0	60
June 30	24	6	54
July 30	18	12	42
August 29	12	18	24
September 28	12	18	6
October 28	18	12	None.
November 27	24	6	None.
December 27	30	0	Begins to fill.

* Wells as Sources of Supplementary Water Supplies. M. L. Fuller, *Engineering News*, Vol. 68, p. 474.

1 to June 1, while the deficiency between June 1 and December 1 varies from 0 to a maximum of 700 000 gal. per day in August and September. Let us consider first what would happen if there were no supplementary supply available. This is indicated in Table XIV, in which figures are in million gallons.

"It is seen that, in the absence of any supplementary supply, the reservoir would be emptied by the middle of October, and that for nearly two months the town would be without a reserve supply and dependent solely upon the daily inflow, which would be far below the demands.

TABLE 15.

CONDITIONS WITH WELLS.

Thirty Days Ending	Regular Supply.	Well Supply.	Deficiency.	Amount Remaining in Reservoir.
May 31	30	6	0	60
June 30	24	6	0	60
July 30	18	6	6	54
August 29	12	6	12	42
September 28	12	6	12	30
October 28	18	6	6	24
November 27	24	6	0	24

"The condition with a supplementary supply from wells of only 200 000 gal. daily, or a fifth of the total consumption, is shown by Table XV. This table brings out the fact that, notwithstanding the apparent insignificance of the ground-water supply and the large shortage in the regular supply, the town would go through the season of drought with undiminished consumption and with a minimum reserve equivalent to a twenty-four days' supply as against two months of absolute exhaustion of reserve when the supplementary well supply was not available."

PROPER DEPTH OF WELLS.

There is an almost universal belief that the quantity of ground water increases with depth, and if a well only "goes deep enough" an adequate supply is certain. This, however, is far from the truth. Practically all ground water has its origin in rainfall, and although there is a general tendency of the water to percolate downward, drilling and deep mining have repeatedly shown that beyond certain moderate depths. the supplies rapidly decrease,

many of the deeper wells and mines being practically destitute of water in their lower portions.* The chief causes of this absence of water are the tightening of the seams under pressure in jointed rocks, the filling of the pores by mineral deposition in the sandstones, the absence of outlets — without which the deep circulation of water is much impeded — in limestones, and the interposition of impervious beds of clay or shale in bedded rocks of any description.

Unfortunately many drillers, although by no means all of them, have immediate profits rather than the future development of the drilling business in view, and are inclined to urge their clients to continue drilling long after there are any reasonable prospects of success. They cannot see that a deep unsuccessful well such as the 3 700-ft. well of Belding Bros. Silk Company at Northampton, Mass., or the 4 000-ft. well of the Winchester Repeating Arms Company at New Haven, Conn., will do more to discourage drilling than several successful wells like the 350-gal. well of the New England Brewing Company at Hartford will do to encourage it.

I presume that many drillers, in their optimism, will take exception to the opinions here expressed. I venture, nevertheless, to present the following brief table of "depth limits" based on the investigations of myself and assistants for the Geological Survey in various parts of the country.

TABLE 16.

"Depth Limits" of Rock Wells.

Quartzite	200– 250 feet
Granite	250– 300 ,,
Shale	300– 400 ,,
Limestone	400– 500† ,,
Sandstone (silty)	400– 500† ,,
Sandstone (open)	1 000–1 500† ,,
Sands and gravels	1 500–2 000† ,,

There will, naturally, be numerous exceptions to the limits indicated, but the additional yields below the depths shown will usually be exceedingly small. If the required volume has not

* Total Amount of Free Water in the Earth's Crust. M. L. Fuller, United States Geological Survey, Water Supply Paper 160, pp. 59–72, 1906.

† Limits largely imposed by the mineralization of the deeper waters.

been secured at these depths, the chances of obtaining a supply from an entirely new well located 100 to 200 ft. or more from the first will ordinarily be at least five times as great as they will be in continuing the original well beyond the limits given.

It should be noted that in the deeper wells the limitations are qualitative rather than quantitative, the waters from below 500 ft. in many of the limestones and below 1 000 to 1 500 ft. in the sands and sandstones often being too mineralized for industrial or boiler purposes and therefore unsuited for public supplies.

CONCLUSION.

In the foregoing pages, I have attempted to indicate the probable average yield of wells in the common types of rocks and unconsolidated deposits encountered in New England. That the supplies in individual cases will depart more or less widely from the estimates is not unlikely. Such variations are bound to follow any attempt to apply average estimates to localities at which the controlling conditions have not been established.

Ground-water problems are seldom simple, and are not to be settled offhand. If given the proper attention, however, they are as susceptible of solution, as has already been stated, as are those of surface supplies. The sooner it is realized that guesswork and rule of thumb are not to be depended upon, but that real investigations are needed, the sooner will the seeking of ground waters be lifted to the plane of other branches of engineering and the sooner will the needless waste in ground-water developments be stopped.

If dependable estimates are required, as they should be in the development of public supplies or other projects involving the expenditure of considerable sums of money, the assistance of a competent engineer who shall have a grasp of the geological as well as the engineering problems will, it goes without saying, be desirable.

Notwithstanding the occurrence and movements of ground waters are dependent almost entirely upon geological conditions, it is by no means the purpose of the writer to advocate the necessity of geological investigations alone, but rather to urge that

geology be recognized, along with hydraulic and mechanical factors, as one of the essential elements to a proper understanding of water-supply problems.

DISCUSSION.

Mr. Allen Hazen.* Mr. Fuller has given us a most interesting paper and one that contains information of permanent character, and the Association is fortunate to have it available for reference in its pages. The paper treats of ground water from various rock formations most fully. In New England, the deposits of sands and gravels are the most important sources of ground-water supply, and this part of the subject will need to be more fully covered on some future occasion.

One aspect of the ground-water supply question has impressed itself forcibly upon the speaker's attention in the last years. That is represented by what the speaker has sometimes called "the coal mine basis" of ground-water supply, which is a very different basis from the one that has been ordinarily studied, and which the author has mainly discussed in his paper. This grows out of the fact that there are in many places great deposits of sand and gravel, the pores of which are filled with water which can be drawn out and used, but which are so situated that when the water is removed it will take long periods, perhaps many years, to refill the pores with water. Where such deposits occur, it is sometimes possible to draw water from them for a time in much greater quantities than could be permanently supplied. Such a supply may be compared to a large lake with a small catchment area. Water can be drawn from such a lake at any desired rate as long as the supply lasts.

I have in mind the case where a group of water companies in the course of a term of years supplied an increasing amount of ground water by driving more and deeper wells, and by so doing have lowered the ground-water level over some square miles of area to an extent ranging up to 50 ft. or more. This is not a permanent source of supply. They have been taking water out of an underground reservoir at a greater rate than the natural flow. The time will come when not only will it be impossible to secure

* Civil Engineer, New York City.

additional water from this source, but it will be impossible to maintain the rate of output that has been reached while the ground-water level was being lowered. Other more distant and expensive sources of supply are clearly required to guarantee future conditions. Nevertheless the use of this ground-water supply has been profitable to the companies, and has brought them to a point where their financial resources will justify a larger and more permanent development.

The whole operation is precisely similar to taking coal from a coal mine. The material is there, it can be taken out, it has a value and can be used at a profit, but when it is gone some other sources of supply must be found.

A similar condition also occurs in gravels near and connecting with the ocean. Here it is sometimes possible to draw out the water in the voids at a much greater rate than it will be replaced, and in this case without lowering the ground-water level because the deficiency is made up by sea water which comes into the space in the ground to take the place of the fresh water that is drawn out. Ultimately, of course, sea water will penetrate to the wells and the water will become brackish, and the supply will have to be abandoned.

Mr. Fuller. I fully agree with Mr. Hazen as to the importance of sands and gravels as sources of public water supplies in New England. Only a few weeks ago I had occasion to recommend a source which, although the rate of replenishment might be less than that of depletion, had a reserve storage sufficient to furnish the required quantities for many years.

Mr. William S. Johnson.* I want to take issue with the author, Mr. President, on one point, and that is with regard to the value of a pumping test in the investigation of ground-water sources. I have personally investigated some hundred pumping tests, and where the tests were thoroughly made and the results properly interpreted, they have never failed to give a correct interpretation both as to the quality and the quantity of the water. Furthermore, in many of these cases it would have been practically impossible to gain the information by any other means.

In several cases in my own practice I have had courage enough

* Sanitary and Hydraulic Engineer, Boston, Mass.

to go ahead and install works without a preliminary pumping test, and in two or three cases at least I have had cause to regret not having gone to the extra expense of such a test, as it would have shown things which I discovered to my sorrow after the works were built.

Here in New England — and all of what I say applies to New England conditions only — there are no extensive deposits of sand or gravel unmixed with other material. It is only necessary to look at some railroad cut to see what the sand is here in New England, near the surface at least. There are streaks of fine sand, clay and other impervious material, the location and extent of which cannot be determined, even by the most expert geologist, and which may upset all calculations in getting a water supply. A pumping test takes all of these things into consideration and shows just what results are to be obtained under the conditions which actually exist without the necessity of theorizing on the basis of assumptions which may not be correct.

A proper test is not "putting down a test well and making a pumping test," as referred to by the author. I agree with him that such a test is of very little value. A proper pumping test is a much more elaborate and expensive proposition. The Massachusetts State Board of Health has probably done more in this line of work than has been done anywhere in this country, and, as a result of their careful studies, not only of the results of the pumping tests but the results of the actual operation of the plants after construction, they have become able to so direct the test and to so interpret the results as to determine with practical certainty everything that it is necessary to know before installing the works.

During a pumping test water should be drawn from the ground at a rate at least as great as it is expected that the draft will be after the works are in operation. The test should be continuous and should extend over a period of from a few days to a few weeks, depending upon the results which are obtained. Observation wells should be located in the vicinity and a complete record of the height of the water in the ground at various places should be kept during the test. Samples should be collected at frequent intervals for chemical analysis.

After the test is completed observations on the wells should be

continued to show the recovery of the ground-water level after the draft ceases. With the results of such a test it is possible to foretell whether or not there would be any rapid deterioration of the water with continued draft from the ground and to tell within reasonable limits the quantity of water which the source is likely to yield continuously.

A thorough pumping test is expensive, and in many cases it seems like a waste of money, especially when the tests prove unsatisfactory. There are cases where the conditions can be foretold without a pumping test with such a degree of certainty that a pumping test is unnecessary, but in the great majority of cases in New England the pumping test is very desirable, if not absolutely necessary, and the results show with certainty what may be expected of the source.

Mr. Fuller. I do not think that there is really any point at issue between us on the pumping question. In my paper, I have said that I do recommend pumping tests. Their limitations, however, must be clearly recognized if conclusions based upon them are to be depended upon. Mr. Johnson has mentioned the complicated character of the exposures in railroad cuts and elsewhere and emphasized the necessity of complete data, especially that furnished by proper pumping tests. This is in direct line of what I am myself arguing for, namely, that all factors must be taken into account. The geological and physical conditions in the vicinity are vital factors of any water problem and must be given due weight in its consideration. Mr. Johnson and I are standing on the same ground, I think. Perhaps I expressed myself unfortunately in calling attention to certain deficiencies, or to certain things a pumping test does not show, but when Mr. Johnson speaks of a pumping test interpreted properly, that interpretation including a physical and geological examination by an experienced party, I am most heartily and thoroughly in accord with him.

I would like to hear what Mr. Weston has to say with regard to what can be told by a pumping test with regard to iron. That is a point with which I am not particularly familiar.

Mr. Robert S. Weston. Regarding the presence of iron, I think there are a good many ground-water supplies in New Eng-

land which showed a practical absence of iron in the beginning, even after a prolonged pumping test, that after ten or fifteen years have shown increases varying from twenty-five to several hundred per cent. That is because the lateral movement of the water through the soil brings a great deal of organic matter to the vicinity of the well, and at that point there is not oxygen enough to burn it as fast as it comes. It accumulates, carbonic acid is produced; the iron is kept in solution, and instead of remaining in the soil in the form of an insoluble iron ore it is gradually dissolved in the well in increasing amount. This is true of a number of supplies, concerning which the speaker showed a table two months ago.*

Again, a pumping test of a short duration may not bring water from beneath a peat bog which may be at some distance away; this water may contain much iron. This phenomenon has been noticed in at least three cases in this state, and as soon as the peat bog water, or the water from beneath the peat bog, gets to the well, even though it comes from a distance, the iron suddenly appears in the supply.

* Journal N. E. W. W. A., Vol. 27, p. 23.

LEPTOMITUS IN DRINKING WATER.

BY ROBERT C. SWEETSER, INSTRUCTOR IN CHEMISTRY, WORCESTER POLYTECHNIC INSTITUTE.

[*Read February 12, 1913.*]

In 1910 the water company which supplies a certain town in Massachusetts built a storage reservoir by damming a small stream which flows through a wooded region. The trees were cut down and removed, and the brush and débris were burned on the bed of the reservoir. None of the soil was removed. The entire area of about 400 acres drained by the stream which feeds the reservoir is uninhabited and covered with a growth of wood. It is inclosed by an impassable wire fence, and the only possible sources of pollution are a few deer, estimated at about sixteen, and smaller game.

In the winter of 1910–11 the reservoir was allowed to fill and no water was drawn from it until the following June. When the gate was opened the water from the outlet pipe was directed upward twenty-five feet or more and then fell in a spray to the bed of the brook, which flowed to another reservoir about one mile below. The course of the brook below the upper reservoir is the original course of the stream before the reservoir was built. The water as it spouted from the gate had a very pronounced and offensive odor, which could easily be detected fifty feet distant. Within a few days a vigorous growth of Leptomitus appeared in the upper portion of the brook, covering the entire bed of the stream in places, and hanging in tufts six inches long from twigs lying in the water. This growth and the strong offensive odor gave the stream a decidedly unsanitary character. It was certainly unusual to see a stream whose character should be the best, judging from the ideal surroundings, assume such an appearance as this. There was, however, no evidence of either the fungus or the odor when the brook reached the lower reservoir, about a mile below. A chemical analysis of the water as it came from the gate gave high nitrogen as free and albuminoid ammonia, high color

and high oxygen consumed. (Table 1.) In other respects the water was about normal. Although the Leptomitus began its growth in the hot weather and flourished during the very hot July of 1911, the water of the brook was quite cold, having a temperature of 50° F. in the upper part of the brook where the growth was heaviest.

TABLE 1.

Chemical Analysis of Brook Water in June and July, 1911.

Parts per Million.

Number	1	2	3	4	5
Date of collection	6–29–'11	6–29–'11	7–16–'11	7–13–'11	7–13–'11
Color	100	100	110	35	38
Odor	Decidedly putrid	Distinctly vegetable	Distinctly vegetable	Slightly vegetable	Slightly vegetable
Total solids	61.0	58.0	62.0	36.5	42.5
Fixed solids	32.0	30.0	30.5	23.5	27.5
Volatile solids	29.0	28.0	31.5	13.0	15.0
Free ammonia	0.170	0.008	0.024	0.008	0.09
Albuminoid ammonia,	0.598	0.166	0.336	0.120	0.056
Nitrites	0	0	0.0008	0.0004	0.0008
Nitrates	0.11	0.07	0.06	0.05	0.05
Oxygen consumed	14.95	8.20	15.10	5.0	6.40
Chlorine	3.50	4.0	3.0	2.0	3.0

1. Outlet of upper reservoir.
2. Lower end of brook near lower reservoir.
3. Lower end of brook near lower reservoir.
4. Lower reservoir near gate house.
5. Faucet in town.

During the winter and spring months the gate of the upper reservoir was closed and the brook below was dry, the town taking its supply during this time from a lower reservoir. June 20, 1912, the gate was opened and by July 1 there was a heavy growth of Leptomitus in the stream, though the amount was considerably less than that of the previous season. At this time analyses were made of the water near the surface of the reservoir, as it came from the gate, and at the lower end of the brook connecting the two reservoirs. The water near the surface of the reservoir had considerably less color, odor, free ammonia, and

oxygen consumed than the water as it emerged from the gate. In three out of four series of analyses, the free ammonia, which was high in the upper portion of the brook, had almost wholly disappeared in the lower portion after flowing a distance of about one mile. (Table 2.)

TABLE 2.

Chemical Analyses of Brook Water in August and September, 1912.

Parts per Million.

Number	1	2	3	4	5
Date of collection	8–5–'12	8–5–'12	9–17–'12	8–5–'12	8–5–'12
Color, Hazen's scale	55	110	50	48	45
Odor, cold	Very slight vegetable	Decidedly putrid	Slightly putrid	None	None
Odor, hot	Slight vegetable	Decidedly putrid	Distinctly putrid	Very slight vegetable	Very slight vegetable
Total solids	48.0	59.0	51.5	39.0	42.0
Volatile solids	18.0	24.0	30.0	18.0	18.0
Fixed solids	20.0	35.0	21.5	21.0	24.0
Albuminoid ammonia,	0.437	0.440	0.335	0.140	0.115
Free ammonia	0.018	0.440	0.240	0.040	0.005
Nitrites	0	0	0	0.004	0
Nitrates	0.05	0.05	0.075	0.105	0.16
Oxygen consumed	11.80	13.00	13.4	7.56	7.40
Chlorine	1.50	2.0	1.5	2.00	2.00

1. Reservoir No. 5. (Upper reservoir.)
2. Outlet of reservoir No. 5.
3. Outlet of reservoir No. 5.
4. Brook just above sand filters.
5. Outlet of sand filters.

The foul condition of the water from the upper part of the brook is, without question, due to the stagnant water remaining for so long a time in contact with the organic matter in the bottom of the reservoir. This vegetable organic matter dissolved in the water and decomposing in the absence of oxygen was the cause of the formation of free ammonia and the offensive odors. The putrefaction of stagnant water at the bottom of a reservoir is, of course, by no means a rare occurrence, as it happens frequently at Lake Cochituate, Jamaica Pond, and elsewhere.

The burning of the brush on the bed of the reservoir just previous to its being filled would necessarily leave a large amount of partially charred material which is more soluble than the unburned or the completely charred vegetable matter. This very likely increased the amount of organic matter in the water of the reservoir during the first season it was used. Early in the summers of both 1911 and 1912 there was a heavy growth of algæ in the reservoir. It was thought at first that this might be a contributing factor to the Leptomitus growth in the stream below. The algæ, however, soon after disappeared and were absent practically the rest of the season.

Mr. Harrison P. Eddy has quite recently called the author's attention to the conditions accompanying a growth of Leptomitus in the sewage effluent at Marlboro, Mass. Here the growth was so vigorous at one time that it covered the bed of the stream to a depth of four or five inches, but has since practically disappeared. An inspection of the chemical analyses of the samples taken during the whole period when the Leptomitus was present does not show the heaviest growth of the fungus at the times of highest free and albuminoid ammonia. (Table 3.) In general, however, it may be said that since 1910, when the growth was the heaviest, it has

TABLE 3.

Sewage Effluent, Marlboro, Mass.

Parts per Million.

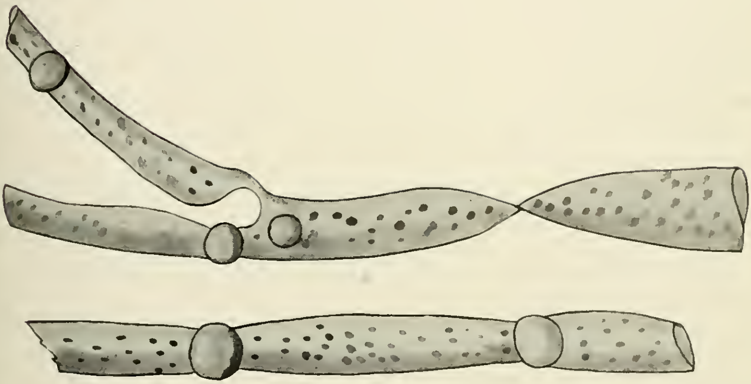
	1908.	1909.	1910.	1911.	1912.
Free ammonia:					
Dec.–May.......	15.98	28.96	16.47	21.73	7.24
June–Nov........	23.44	25.85	10.59	6.33	2.75
Jan.–Dec........	22.27	25.70	13.20	12.63	5.05
Albuminoid ammonia:					
Dec.–May.......	0.72	1.43	0.80	1.04	0.44
June–Nov........	1.21	1.24	0.71	0.29	0.23
Jan.–Dec........	1.10	1.24	0.75	0.61	0.34
Nitrates:					
Dec.–May.......	1.07	1.15	5.59	5.82	10.24
June–Nov........	9.09	5.98	19.05	22.72	26.88
Jan.–Dec........	5.01	4.35	12.56	14.78	18.25
Leptomitus growth .	Small	Medium	Heavy	Medium	Very slight

been disappearing with the gradual improvement of the effluent, that is, as the free and albuminoid ammonia have decreased and the nitrates increased, the Leptomitus has almost disappeared. Another important fact in connection with the growth at Marlboro is that it was much heavier in the colder months. It is also seen from the analyses that, with the exception of 1908, the free and albuminoid ammonia was higher and the nitrates lower during the cold months.

In 1899 the town of Westboro, Mass.,* was troubled with Leptomitus growing on the inner surface of the sewer pipes which conveyed the crude sewage to the filtration works. At times the quantity was so great as to completely obstruct the sewer so that the sewage would flow from the manholes. The sewer was laid for a considerable portion of its length in wet meadow land, and the leakage of ground water into the sewer pipes was excessive, estimated to be more than three times the volume of the sewage. After the rebuilding of the sewer and the exclusion of the greater portion of the ground water, this organism practically disappeared and no further trouble was occasioned by it. At Worcester, Mass., there is a growth of Leptomitus which occurs under conditions similar to those which existed at Westboro. In the early spring the pipe which conveys the raw sewage from the grit chamber to the Imhoff tank becomes clogged with this organism to such an extent that it is necessary to flush it out with a hose. The growth appears at that time of the year when the chemical analysis of the sewage shows it to be diluted to a considerable extent with ground water, which leaks into the pipes. After the pipe is cleaned the growth does not appear again until the following spring.

There seems to be very little literature on the subject of Leptomitus and the conditions favorable to its growth. It is commonly known as a "sewage fungus" and its presence in a stream is considered evidence of sewage pollution in a marked degree. Thresh, in his "Examination of Water and Water Supplies," describes it as "forming tufts of filaments like bits of cotton-wool, though often colored, adhering to stones, twigs, water plants, débris, etc. It is not found in crude sewage, as its growth requires that it should be aërated. It will not flourish in very impure

* Report Massachusetts State Board of Health, 1903, p. 432.



Leptomitus.

Magnified about 750 times.

(After drawing made by J. W. M. Bunker, Ph.D., Harvard University.)

water, but may grow luxuriantly in good sewage effluents." Whipple speaks of it as "being found in pipes conveying sewage, or on the banks of sewage-polluted streams."

As free ammonia in large amounts is always present in streams in which Leptomitus growth occurs, a natural conclusion would be that the free ammonia is in some way responsible for this growth. Their occurrence together can also be explained on the assumption that they both result from the same cause. Fungous growths require organic matter for their food, and it is very probable that more complex decomposition products accompanying the formation of free ammonia are more important factors in the growth of this organism. Such decomposition products if they contain nitrogen are classed as albuminoid ammonia, as this term includes a large number of complex organic compounds, found in water and sewage, representing many stages of decomposition and all degrees of stability. The high free and albuminoid ammonia and the very strong odor in the water from the outlet of the reservoir previously mentioned are decided indications that the organic matter was in a very active state of decomposition. The decrease of the free and albuminoid ammonia and odor, with the disappearance of the Leptomitus in the lower part of the stream leading from the reservoir, might be considered evidence that the albuminoid ammonia exerts an influence on the growth of this fungus. The conditions at Marlboro also indicate that that state of the effluent resulting in the formation of high free and albuminoid ammonia favors the growth of Leptomitus.

Thresh's statement, that Leptomitus requires a well-aërated water, is not perhaps in accordance with our ideas concerning the conditions favorable to its growth. We are familiar with gray fungous growths similar in appearance at least to Leptomitus, in water very foul with putrefying matter. In the work on "Sewage Purification," by Kinnicutt, Winslow, and Pratt, is the following statement: "An interesting change in the fauna and flora accompanies the gradual purification of a stream, and the approximate completion of the task is made obvious, even to the eye, by the characteristics of plant growth. At points of extreme pollution no green growth appears, but only molds and other colorless plants which require organic matter for their food. A grayish or

blackish mass of Leptomitus covers the rocks." My observations, however, made on the outlet of a drinking water reservoir, though limited, seem to confirm Thresh's idea in regard to aëration. This water was forced several feet into the air and fell in a spray to the brook in which were placed miniature dams to provide as much aëration as possible, the object being to remove the foul odor. The bed of the brook is uneven and the heaviest growths appeared in the shallow places and where the water was agitated the most.

Further analyses of the conditions affecting the growth of this fungus give evidence that the free and albuminoid ammonia are not the only factors. In Marlboro, during the years 1908 and 1912, when there was only a small growth of Leptomitus in the effluent, the amount of free and albuminoid ammonia, particularly the free, was higher in some cases than in the outlet of the reservoir in which there was a large growth. Further, the growth in the Marlboro effluent was uniformly heavier in the cold months, but in the year 1908 the ammonias were higher during the warm months. These seeming inconsistencies do not necessarily indicate that the condition of the effluents, as indicated by the high free and albuminoid ammonia, is not a factor in the growth of the Leptomitus, but rather that there are other factors that influence the growth. In Westboro and Worcester, the Leptomitus grew very abundantly in the sewage diluted with a large amount of ground water, but would not grow in the strong sewage. In other words, an increase in the free and albuminoid ammonia was accompanied by the disappearance of this organism. In the outlet of the reservoir and in Marlboro the reverse was true; the fungus grew more abundantly in times of high free and albuminoid ammonia. These constituents of the sewage then apparently are not the sole cause of this growth; there is evidently another factor, and at Westboro this factor was quite conclusively shown to be dilution. Dilution and aëration both produce the same result, both increase the amount of dissolved oxygen in a sewage or water containing a large amount of organic matter. In the four instances cited in which the growth of Leptomitus was observed, there was more or less evidence that dissolved oxygen had a material influence on its growth, and the influence of the free and

albuminoid ammonia in some instances seems to be somewhat obscured and complicated by the amount of dissolved oxygen present.

Heretofore, as far as is known, Leptomitus has not been reported as occurring in drinking water. Although the stream from the reservoir is without doubt unpolluted, its chemical composition is similar in many respects to that of a badly polluted water, the principal difference being that in this water the source of contamination is vegetable putrefying matter instead of animal. Such being the case, Leptomitus might be more properly called a "foul-water fungus" rather than a "sewage fungus."

My conclusions drawn from the observations made of the growth of Leptomitus in the stream formed from the outlet of a reservoir, and from information gathered from other sources, are that aëration or sufficient dilution and free and albuminoid ammonia or organic matter in an active state of decomposition are all favorable to the growth of this fungus. There is also considerable evidence that a low temperature favors its growth. And finally, that Leptomitus is not always an indication of sewage pollution.

The observations upon which these conclusions are based are limited in number and incomplete, and I should be interested to know of observations by others which are either corroborative of or contradictory to them.

It may be interesting to add that while the water as it came from the outlet of the upper reservoir in the town first mentioned had a color of 100–130, and a strong offensive odor, after flowing a mile through the brook to a lower reservoir, and from here through service pipes to the town, its color dropped to 40 and the odor had wholly disappeared. The foul condition of the brook lasted all summer, but the water in the town caused no complaints from the consumers. In an attempt to kill this fungous growth the brook was diverted from its course, and when the growth became troublesome in the brook in its new course, the water was turned back into its original channel, which in the meantime had been thoroughly cleaned. In this way the growth was in a large degree checked. Fragments of Leptomitus were continually becoming detached and floating down stream, and it was feared by

this means the growth might spread to the lower reservoir. To prevent this a wooden sluice-way was constructed in the stream and in this were placed cloth screens. This precaution proved unnecessary, as the growth did not extend down the stream to the screens. Later, sand filters were constructed at the lower end of the brook just as it enters the lower reservoir. There is no sedimentation of water before it runs on to the filters, and there forms on the filters a black deposit of decayed vegetable matter, which is evidently mixed with sufficient Leptomitus which has floated downstream to give the deposit a rather slimy consistency. This clogs the filters badly and necessitates scraping about every two days. The water from the filters is clear and odorless.

DISCUSSION.

Prof. William T. Sedgwick.* It is an old custom showing the early stages of a science, to affirm that a particular thing is the cause of some other thing, and the sole cause. Pasteur, for example, found that what he believed to be "the" vinegar microbe and also "the" microbe that would sour milk. But to-day we know that there are many microbes that will sour milk and quite a number that will feed on alcohol and produce vinegar. Then we used to hear much about "the" sewage fungus Beggiatoa. But we don't hear so much about it nowadays. It is recognized that Beggiatoa may grow in sewage or it may not, and that you cannot be sure that you have got sewage wherever you get Beggiatoa.

And so it has been with Leptomitus. The testimony has been that wherever Leptomitus is, sewage must be, or have lately been. When, therefore, Professor Sweetser told me that he had found Leptomitus in a drinking water stream flowing from a good reservoir, I saw that the Leptomitus myth had got to go; and I was quite ready to see it go, because I have always been skeptical about such simple things as the Leptomitus-sewage doctrine since I began to know about Pasteur and other cases.

Now I think this paper is exceedingly interesting. It is interesting in a great many ways. In the first place, it shows once

* Massachusetts Institute of Technology, Boston, Mass.

more that the bottoms of our reservoirs are, as we know, not infrequently in a condition which to a layman would suggest sewage. Reductions go on there in the absence of oxygen which give rise to excessive amounts of free ammonia and to rearrangements of the albuminoid materials, and also to the diminution of nitrates. In other words, a whole lot of obscure changes are going on in the bottom of these reservoirs, which are now well known, of course, to you gentlemen, and yet when they were first worked out in this neighborhood by Mr. Stearns and Professor Drown and Mrs. Richards, and others, were a great surprise to all of us. You can draw up, as you know, from the bottom of a good many fine looking ponds abominable looking water and abominable smelling water, just as you can sometimes get from deep wells water that is anything but attractive.

And the reason is perfectly clear. There is oftentimes a lack of oxygen down there, and an abundance of microbes or, at least, a sufficient number of microbes capable of living under those conditions, and a lot of chemical changes take place there which yield undesirable and unexpected products. I have no doubt that under certain conditions the outflow taken from the bottom of a good many reservoirs might give support to Leptomitus and other fungi. But here is the first case I know of, reported and studied with thoroughness and painstaking care by Professor Sweetser.

He has raised the question, What is it that supports the Leptomitus? Here again we naturally seek for a simple and easy explanation. I suggested to him that very likely it was the free ammonia. That was as good a guess as any other, because sewage contains free ammonia, and so does water from the bottom of many of our ponds. But, on the other hand, Leptomitus is a fungus, it is destitute of chlorophyll, and fungi ought not to live on free ammonia; they ought not to have much to do with nitrates. They have got to have richer food than either of those. And so we have to turn to the albuminoid ammonia, — that unknown land in which so many chemical compounds exist, and where so many things go on that nobody knows anything about. The things represented by albuminoid ammonia we know very little about; they may be of one sort or another. Apparently they are of many sorts. And it would seem that among these, together with the

presence of oxygen and, perhaps, the presence of considerable free ammonia, chemical rearrangements take place by which this organism gets a natural and necessary food. But what that natural and necessary food is, no man knows. Each organism is more or less delicately adjusted to its environment, and its environment more or less delicately adjusted to it.

When we think of Leptomitus growing near the mouths of sewers, as we find it, for example, in the Nashua River at Fitchburg, down below some of the sewer outfalls, you have got a good deal the condition described by Professor Sweetser as probably requisite, namely, decomposing organic matter, which in a chemical analysis would appear largely as albuminoid ammonia, free ammonia, oxygen brought in by the flowing stream, and dilution. At any rate, never again shall we be able to say that Leptomitus certainly indicates sewage pollution. All we can say is that it apparently means foul water. We don't get it growing in waters even when they are high in albuminoid ammonia or even when they contain a great deal of free ammonia, after they are aërated. We get it, apparently, connected with putrefaction in some way, either putrefaction at the bottom of a reservoir or putrefaction in a sewer.

Mr. Robert S. Weston.* I had occasion to observe this Marlboro effluent brook and can testify as to the abundance of growth at one time and to the disappearance of the organisms after the condition was better. I am inclined to think that there must be some condition of the organic matter produced by decomposition in the bottom of a reservoir, where it is in such a condition that it rapidly (with the help of Leptomitus) unites with oxygen, when exposed in a brook. Ordinarily the organic matter, as I understand it, undergoes a rather slow decomposition through the agency of bacteria, but here the fungus seems to take the place of the bacteria and effects a very rapid change in the organic matter which has been prepared by decomposition for the growth or as the food of the Leptomitus.

A man named O. Spitta, in Berlin, has done a great deal of work on the character of the Spree River as it flows through Berlin, and has found around sewer storm overflows in the Spree, where

* Consulting Sanitary Engineer, Boston, Mass.

there has been a good deal of decomposed sewage going into the water, zones of algæ, and these zones, not only of algæ but of fungi, grow right at the outlets of the sewers. It seems as if these cases are analogous to those of Professor Sweetser.

I remember observing when in Beverly last fall with Mr. Blackmer a rather highly contaminated water from a brook draining the bottom of a reservoir, and flowing into a lake, where for a space of 20 ft. out from the point of entrance were numbers of organisms, evidently scavengers waiting for the digested organic matter which was being carried from the brook into this lake. Probably further investigations by Professor Sweetser would show that there is the same preparation of organic matter in the bottom of a reservoir which makes so good a food material for the Leptomitus, that a little aëration causes the two to combine readily and oxidize the water more rapidly than by bacterial oxidation.

PROCEEDINGS.

Hotel Brunswick,
Boston, Mass., February 12, 1913.

The President, Mr. J. Waldo Smith, in the chair.

The following members and guests were present:

Honorary Members.

W. T. Sedgwick and F. P. Stearns. — 2.

Members.

C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, Dexter Brackett, E. C. Brooks, George Cassell, J. C. Chase, R. D. Chase, A. O. Doane, E. D. Eldredge, F. F. Forbes, M. L. Fuller, A. S. Glover, J. A. Gould, F. H. Gunther, R. A. Hale, R. K. Hale, A. R. Hathaway, M. F. Hicks, A. V. Howes, J. L. Hyde, G. R. Jones, F. T. Kemble, E. W. Kent, Willard Kent, G. A. King, N. A. McMillen, A. E. Martin, W. E. Maybury, John Mayo, J. H. Mendell, F. E. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, T. A. Pierce, H. E. Perry, L. C. Robinson, C. W. Sherman, J. Waldo Smith, G. H. Snell, F. N. Speller, G. A. Stacy, R. H. Stearns, E. L. Stone, H. L. Thomas, R. J. Thomas, J. L. Tighe, E. J. Titcomb, G. W. Travis, C. H. Tuttle, W. H. Vaughn, R. S. Weston, F. I. Winslow, G. E. Winslow, I. S. Wood. — 60.

Associates.

Builders Iron Foundry, by A. B. Coulters and D. K. Bartlett; Chapman Valve Manufacturing Company, by J. F. Mulgrew; Darling Pump and Manufacturing Company, Ltd., by H. M. Pickersgill; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey and R. D. Wertz; Platt Iron Works Company, by F. H. Hayes; Rensselaer Valve Company, by C. L. Brown; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by E. K. Otis; Water Works Equipment Company, by W. H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison and W. F. Bird; National Tube Company, by H. T. Miller. — 24.

Guests.

Prof. R. C. Sweetser, Henry C. Page, Worcester, Mass.; George W. Barrett, Lowell, Mass.; Harry Greenhalgh, Fall River, Mass.; E. H. Eldredge, Onset,

Mass.; I. M. Lowe, East Weymouth, Mass.; F. N. Strickland, Westfield, Mass.; George G. Manuel, Natick, Mass.; J. E. Parker, Somerville, Mass., Z. R. Forbes, Brookline, Mass.; and J. Siegel, Cleveland, Ohio. — 11.

The Secretary read the minutes of the annual meeting, and no objection being made, they were declared approved.

An application for membership was presented from M. S. Fuller, Winslow, Me., trustee Kennebec Water District, properly recommended and endorsed by the Executive Committee. The Secretary was instructed to cast the ballot of the Association in favor of the election of Mr. Fuller, and he having done so the gentleman was declared duly elected a member of the Association.

The President. We all regret that there are not more new members coming into the Association. Those of us who were here last month remember that there was reported a net falling off for the year 1912. This is a matter that the officers of the Association cannot do much about, but it is something that every member should take a vital interest in, and each one of us should try to induce some one to join the Association. I would suggest that before the next meeting we all try and see if we cannot bring in a new member, so that the membership of the Association may be put back to where it was and show an increase.

The Secretary has received the following letter, which I will read:

Bureau of Water.
Department of Public Works.
City of Philadelphia.

February 10, 1913.

Mr. Willard Kent, *Secretary*,
New England Water Works Association,
Tremont Temple, Boston, Mass.

Dear Sir, — On behalf of the Bureau of Water of this city, I extend a very cordial invitation to the New England Water Works Association to hold its next September convention in Philadelphia.

I do not recall that the Association has ever met in this city, and it is a number of years since it has met in this vicinity.

I think the members of the Association will find a great deal of interest not only in the water supply, but in the city itself.

Very truly yours,
(Signed) Carleton E. Davis,
Chief of Bureau.

At a meeting of the Executive Committee this morning, after views had been expressed by the different members, it was voted to hold the next annual convention in Philadelphia the second week in September, on Wednesday, Thursday, and Friday.

In this connection I may say that I saw Mr. Davis about two weeks ago and he brought the matter to my attention and said that both the director and himself were very much interested and were very anxious that the Association should come to Philadelphia, and that they believed without doubt they could make it not only interesting but very pleasant for the members during three days' stay in the city. It seems to me that it is a very excellent opportunity for us to go there now as there is so much of interest for water-works people in the filtration and pumping plants; and it is a particularly favorable time, perhaps, for one of our members holds a prominent position down there under a reform administration which is trying to do great things for Philadelphia. The mayor is a very interesting man, always very cordial to strangers, and I think those of us who had the pleasure of enjoying the hospitality of the city last fall will heartily endorse our choice of the place for our next annual meeting.

Mr. Brooks has a matter he would like to bring to your attention.

Mr. Edwin C. Brooks.* I have been requested to ask the following question: "Does any city, town, or water company, where there are two or more tenements in a house, set meters to cover the use of each tenement separately, and if meters are thus set, are the bills made to the owner or to the tenants?" I have been requested to ask if any of the members know of any cases where that is the practice.

Mr. George W. Travis. In Natick we have several such cases, and we insist that the meters be set separately for each tenement. The bills are sent as an accommodation to the tenants but charged to the owners.

Mr. Francis T. Kemble. We have the same in New Rochelle. We insist on separate meters.

Mr. Lewis M. Bancroft. The same in Reading.

A Member. The same in Wellesley.

Mr. Ralph H. Stearns. At Hartford meters are only set

* Superintendent Water Works, Cambridge, Mass.

separately for the different apartments of a tenement when requested and the extra meters paid for by the property owners. The bills for water are always rendered to the owners.

Mr. William Naylor. Our rules in Maynard provide that one meter shall be set on a service. If parties want to divide the service we set the meters and charge $1.25 a year for them, we laying the necessary pipe to the meters, and the bills are made out to any one the owner wishes. The owner of the property, however, is held responsible.

The President. At the annual meeting a report was received from Mr. Baker, the chairman of the Conservation Committee, enclosing a letter from Mr. Pinchot upon the subject of national forest lands, asking that the Association take action favoring the retaining of the control of public forest lands in the national government rather than passing it over to the several states. A vote was passed requesting the chairman of the committee to prepare a resolution to submit at this meeting, and I have the following from Mr. Baker:

505 Pearl Street, New York,
February 7, 1913.

Mr. Willard Kent, *Secretary*,
New England Water Works Association,
Tremont Temple, Boston, Mass.

Dear Sir, — In accordance with what I understand was the expressed desire of the Association, at its January meeting, I have drafted a resolution for submission to the Association, against the turning over of national forest lands to the several states. The resolution is as follows:

"*Resolved*, that it is the sense of the members present at this meeting that the public forest lands of the United States should be retained in the control of federal government and should not be turned over to the several states within which such lands are located.

"*Be it further resolved*, that a copy of these resolutions be sent to the Congressmen representing the New England states and to the Congressmen of such other states as the President and Secretary in their discretion may elect."

Respectfully submitted,
(Signed) M. N. Baker,
Chairman Conservation Committee.

This resolution is proposed for adoption; what will you do with it?

Mr. Frederic P. Stearns moved that the resolution be adopted, and it was adopted by a unanimous vote.

The President then announced that the paper presented at the annual meeting by Robert J. Thomas, on "The Water Works of the City of Lowell and Some Recent Improvements," discussion of which was at that time postponed on account of the lateness of the hour, was now before the Association. The discussion was opened by Mr. Thomas, and was participated in by Mr. F. F. Forbes, Mr. Robert S. Weston, and Mr. R. D. Chase.

Prof. Robert C. Sweetser, Worcester Polytechnic Institute, Worcester, Mass., then read a paper on "The Occurrence of Leptomitus in a Drinking Water Stream." The paper was discussed by Professor Sedgwick and Mr. Robert S. Weston.

A paper prepared by Mr. William R. Conard, inspecting engineer, Burlington, N. J., in the absence of Mr. Conard was read by Mr. George A. Stacy. It was discussed by Mr. Chase, Mr. Leonard Metcalf, and Mr. Robert S. Weston.

Mr. Charles W. Sherman, principal assistant engineer with Metcalf & Eddy, Boston, Mass., gave an account of a visit he recently made to Cuba and a description of certain features of the water-supply plant for the United Fruit Company's plantations.

Mr. Leonard Metcalf called the attention of the members to a matter upon which he was at work, with a committee of the American Water Works Association, in which he desired the assistance of the members of the New England Water Works Association. He said:

"We are trying to assemble information concerning the practice in this country as to charging for private fire protection service. A circular will be sent out by the American Association very shortly, asking for information: first, as to the sizes of taps permitted and the charges made; second, as to the method of locating private fire hydrants; and, third, as to sprinkler systems. I should be very grateful to any of you who will send me a schedule of charges which you have in your works for that class of service. I am very anxious to see what the practice is in different parts of the country, and to see if the practice cannot be standardized.

"I am glad to say that the insurance men have taken a very friendly attitude, and I hope that we can get together on a standard

practice in a way which will be to the advantage of all concerned.

"I may say that in the paper which I presented before the American Association a year or two ago, in connection with Mr. Kuichling and Mr. Hawley, on the reasonable basis for fire protection charges, we were dealing with public fire protection. This inquiry which is now making deals essentially with private fire protection."

THE PRESIDENT. I think this inquiry will bring out a great deal of interesting information, and will show that there is a wide divergence in practice in relation to charging for so-called fire supply. It seems to me, perhaps, the private water companies, who are in the business commercially, will in this case be able to contribute to the general information.

Adjourned.

HOTEL BRUNSWICK,
BOSTON, MASS., March 12, 1913.

The President, Mr. J. Waldo Smith, in the chair.

The following members and guests were present:

MEMBERS.

C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, F. K. Betts, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, Dexter Brackett, G. S. Brown, G. A. Carpenter, J. C. Chase, R. D. Chase, R. C. P. Coggeshall, M. F. Collins, J. H. Cook, J. A. Cushman, E. D. Eldredge, G. F. Evans, F. F. Forbes, A. D. Fuller, M. L. Fuller, F. J. Gifford, A. S. Glover, R. A. Hale, F. E. Hall, A. R. Hathaway, Allen Hazen, H. G. Holden, J. L. Howard, A. C. Howes, J. L. Hyde, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, Morris Knowles, N. A. McMillen, A. E. Martin, W. E. Maybury, G. F. Merrill, H. A. Miller, William Naylor, F. L. Northrop, T. A. Peirce, L. C. Robinson, P. R. Sanders, A. L. Sawyer, J. Waldo Smith, G. H. Snell, W. F. Sullivan, L. D. Thorpe, J. L. Tighe, D. N. Tower, C. H. Tuttle, W. H. Vaughn, R. S. Weston, G. C. Whipple, G. E. Winslow and H. B. Wood. — 61.

ASSOCIATES.

Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by C. E. Pratt and J. F. Mulgrew; *Engineering Record*, by I. S. Holbrook; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer;

Ludlow Valve Manufacturing Company, by A. R. Taylor; Charles Millar & Son Co., by C. F. Glavin; Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by R. D. Wertz and H. H. Kinsey; Norwood Engineering Company, by C. E. Childs; Pittsburgh Meter Company, by V. E. Arnold and J. N. Turner; Platt Iron Works Company, by F. H. Hayes; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simmons; Henry R. Worthingt n, by W. F. Bird. — 27.

GUESTS.

C. W. Gilbert, Woburn, Mass.; Burt B. Hodgman and O. L. Lincoln, New York, N. Y.; Jack Siegel, Cleveland, Ohio; Robert Robertson, water commissioner, Beverly, Mass.; Harry Greenalch, Fall River, Mass.; J. E. Parker, Somerville, Mass.; F. M. Strickland, Westfield, Mass.; Wm. Tierney, Dayton, Ohio; Frederick E. Tupper, Quincy, Mass.; Arthur E. Hatch, Boston, Mass., and Frank Morsburg, Attleboro, Mass. — 12.

The Secretary presented applications for membership, properly endorsed and recommended by the Executive Committee, from the following:

Thaddeus Merriman, Essex Falls, N. J., assistant to chief engineer, Board of Water Supply, City of New York; Milton W. Davenport, New Britain, Conn., chemist, City of New Britain Water and Sewage Works; Richard H. Gould, Poughkeepsie, N. Y., with R. J. Harding, consulting engineer; J. Stewart Buzby, Moorestown, N. J., principal assistant with W. R. Conard, Burlington, N. J.; Robert C. Sweetser, instructor of chemistry, Worcester Polytechnic Institute, Worcester, Mass.; P. J. Kelley, Salem, Mass., director Public Works; Willard M. Gooding, Berlin, N. H., assistant with R. S. Weston, and acting superintendent, Berlin, N. H., Water Company; Joseph E. Conley, Norwood, Mass., superintendent Sewer and Water Department; William R. Edwards, Paterson, N. J., superintendent Meter Department, Passaic Water Company, Paterson, N. J.; James A. McMurray, Dorchester, Mass., engineer Water Service, Public Works Department, City of Boston; Frank Mossburg, Attleboro, Mass., water commissioner.

On motion of Mr. Thomas A. Peirce, the Secretary was in-

structed to cast the ballot of the Association in favor of the applicants whose names had been read, and he having done so they were declared elected members of the Association.

The report of the Committee on Water Consumption and Statistics Relating Thereto, Leonard Metcalf chairman, Frank J. Gifford, and William F. Sullivan, was then presented. It was discussed by Messrs. Metcalf, Allen Hazen, Morris Knowles, A. F. Ballou.

Mr. George C. Whipple, professor of sanitary engineering, Harvard University, then presented a synopsis of his paper, which was read by its title at the February meeting, on "Decarbonation as a Means of Removing the Corrosive Properties of Water."

Mr. Richard A. Hale moved that the discussion of the paper be postponed until the annual convention in September.

The President. I think it is important that this paper should receive a full discussion, and between now and the time of the annual convention the paper will have been printed and every one will have had an opportunity to study it and be in position to present such discussion as is desired.

The motion to postpone the discussion was adopted.

Mr. Myron L. Fuller, geological engineer, Boston, Mass., then read a paper entitled, "Quantitative Estimation of Ground Waters for Public Supplies." The paper was discussed by Mr. Allen Hazen, Mr. William S. Johnson, and Mr. R. S. Weston.

The President. Before the adjournment of this meeting, I want to call attention again to the report which has been presented this afternoon on water consumption and the statistics relating thereto. This Association has always enjoyed an enviable reputation for the high character and the completeness and usefulness of the reports presented from time to time by the special committees; and this report which has been presented this afternoon is not only of great importance but of great interest to every waterworks man. I earnestly request that the members will not put this away in a pigeonhole, but will examine it at an early day, and will communicate their views to the chairman of the committee, Mr. Metcalf, or to the Secretary of the Association, Mr. Kent. It may look rather formidable, but the recommendations are not

so numerous, and certainly every one can examine the recommendations and present his views regarding them.

Mr. Allen Hazen. Mr. President, we had a committee on meter rates, some years ago, of which Mr. Coffin was chairman, and he made a report which is a classic. He treated the subject in a way it had never been treated before. But since that time there have been many developments in water-works management, and I think that the time has now arrived when the meter rate question can be taken up and standardized to a greater extent than it has been, with great advantage to the Association. I therefore move that a committee be appointed to take this matter up and to report at some later date.

The President. How shall the committee be appointed, Mr. Hazen?

Mr. Hazen. Following the custom, I think it would be for the chair to appoint the committee.

The President. Will you suggest the number of the committee?

Mr. Hazen. I think that will be within the discretion of the President.

The motion was adopted. The President subsequently appointed the following committee: Messrs. Allen Hazen, Charles R. Bettes, Arthur E. Blackmer, Allen W. Cuddeback, and James L. Tighe.

Adjourned.

Bass Point, June 11, 1913.

The June meeting of the New England Water Works Association was held at Bass Point and Beverly, Mass., on June 11, 1913.

The following members and guests were present:

Members.

J. M. Anderson, H. B. Andrews, L. M. Bancroft, A. E. Blackmer, J. W. Blackmer, E. C. Brooks, F. L. Cole, John Doyle, E. D. Eldredge, G. F. Evans, M. L. Fuller, T. C. Gleason, A. S. Glover, R. K. Hale, F. E. Hall, G. A. Heffernan, J. L. Howard, A. C. Howes, Willard Kent, G. A. King, C. F. Knowlton, J. N. McKernan, H. V. Macksey, D. E. Makepeace, W. E. Maybury,

John Mayo, F. E. Merrill, H. A. Miller, F. F. Moore, F. L. Northrop, C. D. Peirce, J. J. Philbin, A. L. Sawyer, J. Waldo Smith, Sidney Smith, G. H. Snell, G. A. Stacy, G. T. Staples, R. L. Tarr, E. J. Titcomb, L. J. Wilber, F. B. Wilkins, F. I. Winslow and G. E. Winslow. — 44.

Associates.

Ashton Valve Company, by H. H. Ashton; Chapman Valve Manufacturing Company, by H. L. DeWolf; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; Charles Millar & Sons Co., by C. F. Glavin; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey and R. D. Wertz; Pittsburg Meter Company, by J. W. Turner; Rensselaer Valve Company, by C. L. Brown; Ross Valve Manufacturing Company, by Wm. Ross; A. P. Smith Manufacturing Company, by F. L. Northrop and D. F. O'Brien; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison and W. T. Bird. — 20.

Guests.

Mrs. H. H. Kinsey, Mrs. F. I. Winslow, Mrs. H. A. Miller, Mr. Horace Carpenter, and Mr. V. B. Perry, Boston; Mr. F. S. Hamlin, Mrs. E. C. Brooks, Cambridge; Mrs. G. T. Staples, Miss Grace M. Staples, Dedham; Mrs. L. M. Bancroft, Reading; Mr. Patrick Gear, Miss Catherine Sullivan, Miss Ellen Hanley, Holyoke; Mrs. George E. Winslow, Waltham; Miss Ida Brown, Malden; Mr. Charles Bowman, Mr. Frank E. Smith, Andover; Mrs. John Mayo, Miss Hopkins, Bridgewater; Mrs. G. A. Stacy, Marlboro; Mrs. C. F. Knowlton, Mr. Peter J. Cannon, Clinton; Mrs. W. E. Maybury, Mrs. E. H. Capen, Capt. P. A. Mock, Capt. A. S. Smith, Braintree; Mrs. J. W. Blackmer and Mr. Robert Robertson, Beverly; Master Neddie Eldredge, Onset; Mrs. F. F. Moore, Hawthorne, N. Y.; Mrs. F. B. Wilkins, Milford, N. H.; Mrs. L. G. Wilber, Brockton, Mass.; Mr. F. B. Wilkins, Woonsocket, R. I.; Miss Moye, East Providence, R. I. — 34.

The Secretary read applications for membership, duly approved, from Edmund J. Lonergan, Malden, Mass.; Frank O. Sinclair, Burlington, Vt.; Edgar F. Smith, New York, N. Y.; George H. Hazlehurst, Wilmington, N. C.; and P. A. Shaw, Lancaster, Pa.

The Secretary was empowered to cast the ballot of the Association in favor of the candidates, and, he having done so, they were declared by the President duly elected members of the Association.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Boston, Mass., Wednesday, February 12, 1913.

Present: President J. Waldo Smith, and members M. F. Hicks, G. A. Stacy, J. L. Tighe, J. W. Blackmer, L. M. Bancroft, R. K. Hale, G. A. King, and Willard Kent.

Application of Mr. M. S. Fuller, trustee Kennebec Water District, Waterville, Me., was received and recommended for membership.

Communication was received from Mr. M. N. Baker, chairman of the Committee to look after and keep track of legislation and other matters pertaining to the Conservation, Development and Utilization of the Natural Resources of the Country.

It was voted that the Executive Committee recommends that the Association take the action suggested by Mr. Baker.

Communication was also received from Mr. C. E. Davis, inviting the Association to hold its convention at Philadelphia, Pa., and it was unanimously voted that the next annual convention be held in Philadelphia on the 10th, 11th and 12th of September next, and that the President be and is hereby authorized to appoint a committee of arrangements.

Discussion was had in reference to the June outing and a committee consisting of W. E. Maybury, J. W. Blackmer, and C. W. Sherman was appointed to investigate and report, with recommendations, at the March meeting.

The President was by vote authorized to deputize, at his discretion, both the first and second Vice-Presidents to approve bills and countersign checks on occasions of his absence.

It was voted that no meeting of the Association be held in April of the present year.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Boston, Mass., March 12, 1913.

Present: President J. Waldo Smith, and members F. A. McInnes, Leonard Metcalf, W. F. Sullivan, G. A. Stacy, J. L. Tighe, J. W. Blackmer, L. M. Bancroft, G. A. King, and Willard Kent.

Ten applications were received and recommended for membership, namely:

For membership: Joseph E. Conley, superintendent Sewer and Water Department, Norwood, Mass.; Robert C. Sweetser, instructor Worcester Polytechnic Institute, Worcester, Mass.; P. J. Kelley, director Public Works, Salem, Mass.; James A. McMurry, engineer water service, Public Works Department, Boston, Mass.; Willard M. Gooding, acting superintendent Water Company, Berlin, N. H.; Frank Mossburg, water commissioner, Attleboro, Mass.; W. R. Edwards, superintendent Meter Department, Passaic Water Company, Paterson, N. J.; Thaddeus Merriman, assistant to chief engineer, Board of Water Supply, New York, N. Y.; Richard H. Gould, sanitary engineer, Poughkeepsie, N. Y., J. Stewart Buzby, inspecting engineer, Moorestown, N. J. — 10.

One member was reinstated.

The President and Secretary were added to the committee on the June meeting, and said committee was authorized to fix the date and place and complete all arrangements therefor.

Adjourned.

Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association on board steamer *King Philip* en route to Beverly, Mass., Wednesday, June 11, 1913.

Present: President J. Waldo Smith, and members George A. Stacy, James W. Blackmer, Willard Kent, Lewis M. Bancroft, Richard K. Hale, and George A. King.

Five applications for membership were received and recommended for admission, namely, Edmund J. Lonergan, Malden, Mass.; Frank O. Sinclair, Burlington, Vt.; Edgar F. Smith, New York, N. Y.; George H. Hazlehurst, Wilmington, N. C.; and P. A. Shaw, Lancaster, Pa.

Adjourned.

WILLARD KENT, *Secretary.*

New England Water Works Association.

ORGANIZED 1882.

Vol. XXVII. September, 1913. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

METHOD OF LOCATING LEAKS IN WATER MAINS.

ERRATUM.

Insert at page 46, Volume 27, March, 1913, Table 5, Water Consumption of Cities:

Charleston, S. C., population, 58,800, 1912.

Since then several engineers connected with the Inspection Department have successfully used the method in locating leaks in large, complicated yard pipe systems after the resources of the mill have been exhausted without success. In one case one of our engineers assisted the superintendent of a public water works in locating a bad leak in a paved street where it was thought that the whole street would have to be dug up.

Caustic soda was selected in preference to many other possible materials for several reasons. It gives a very sharp indication, is not particularly poisonous, and in the dilute solutions required has no objectionable color, taste, or smell and does no damage to pipes, gates, or fittings. Carbonate of soda, that is, washing soda, or soda ash, will work equally well. The method can be used on public systems by taking the precaution to shut off domestic connection while the measurements are being made, and flushing the pipes afterward as explained.

After locating the leak within reasonable limits by use of section valves and meters its magnitude should be determined by placing a small meter around a closed valve.

No pipe system with much underground pipe can be expected to be absolutely tight. Several careful estimates have been made on well-laid new pipe. About three gallons per day per foot of lead joint is probably a fair average, or approximately 600 gallons per day per 1 000 feet of pipe of sizes commonly found in yard pipe systems, that is, 6 in., 8 in., and 10 in., with an average number of fittings.

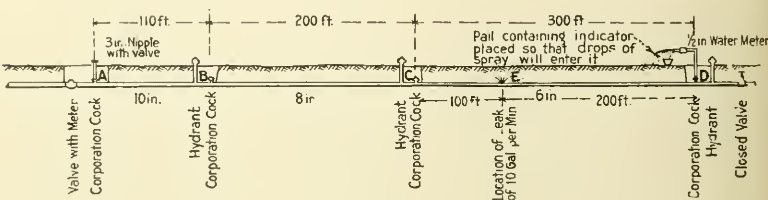


FIG. 1.

Contents of pipe between A and B = 110 x 4.08 = 449 gal.
Contents of pipe between B and C = 200 x 2.62 = 524 gal.
C and E = 100 x 1.47 = 147 gal.
E and D = 200 x 1.47 = 294 gal.
Contents of pipe between C and D = 300 x 1.47 = 441 gal.

Fittings such as check valves, post valves, or drip valves where leaks could occur should be carefully examined. Not infrequently it has been found that a considerable leak was from a poorly packed valve spindle or an imperfectly seated check valve. Sometimes sprinkler drip valves discharge into sewers in such a manner that a small stream of water may trickle through unobserved. Leaks in hydrants are not uncommon. It must be remembered that a half dozen insignificant leaks flowing for twenty-four hours a day may add up to a large amount in the course of a year.

After determining the amount of the leak and its approximate location by use of section valves, the following will be found useful in locating the leak without digging up all the pipe.

The letters refer to Fig. 1, representing a typical example.

Alkali is introduced into the piping as near as possible to the source of supply. This point is marked " A " on the sketch. A $\frac{1}{2}$-in. or $\frac{3}{4}$-in. hole is tapped in the pipe by use of a pipe tapping machine such as is commonly used by the public water works.

To the corporation cock at " A," which is left in the pipe after it is tapped, a 3-in. nipple about 18 in. long is attached with a reducing coupling and nipple at the lower end and a 3-in. valve at the upper end to prevent the water from flowing out. When in place the corporation cock is opened a small amount and the 3-in. nipple allowed to fill with water. Then two or three pounds of solid caustic soda or potash is placed in this 3-in. nipple, the valve closed, and the corporation cock opened so that the caustic solution can diffuse into the pipe. The time that the corporation cock is opened is noted.

If a pump is used for supplying the pressure, great care must be taken that the valve from the primary supply is tight, and that a steady pressure higher than the primary water supply is maintained, otherwise the air in the sprinkler system will cause false indication. Tank or public water of uniform pressure is much easier to manipulate. It is essential, of course, that no water be taken from the system except for measurement while the experiment is going on.

After the alkali has been in the pipe long enough to have arrived at " B," being carried by the leak of 10 gal. per minute, that is, 449 gal. divided by 10 gal. equals 44.9 minutes, a few spoonfuls of water are drawn from the cock at " B " in a pail containing a half teaspoonful of the phenolphthalein indicator. If the red color appears, this shows that all the leak is beyond. If the color should not appear, samples should be tested at minute intervals for fifteen or twenty minutes. If a test is finally obtained, there are probably two or more leaks, part between " A " and " B " and part beyond. At the time calculated for the alkali to appear at " C," tests as above should be repeated at " C." Then at " D," when it is found after waiting ten or fifteen minutes that the alkali has not appeared at " D," a meter should be attached here, read, and the water drawn off until a test is obtained. As soon as red color appears in the pail, the flow should be stopped and the meter read. The difference in the readings represents

the contents of the pipe between "D" and "E," or in the example, 294 gal. This divided by 1.47, the capacity of the pipe in gallons per foot, gives 200 ft., or the distance back along the pipe from "D" to "E."

After completing the test, the hydrant at "D" should be opened and the caustic carefully washed out of the pipes.

If the pipe is level or slants towards "D," a point nearer "D" will probably be indicated, as the caustic solution is heavier than water and tends to flow downward under the water.

With a pipe sloping downward from the source of water to the leak, the indications will be unreliable. With one sloping upward, they will be accurate within the limits of the conditions of the experiment. Very frequently there is not one single leak but several, in which case find first the leak nearest "D." After this is stopped, repeat the experiment, finding that next further away and so on until all are found.

The phenolphthalein solution is formed by dissolving the dry powder, which may be purchased at any chemical supply store, in the proportion of ⅛ ounce in a pint of wood alcohol.

This method will not be found of much service for single leaks of less than one or two gallons per minute.

Hydrants and calibrated nozzles can be used instead of corporation cocks and meter for preliminary or approximate determinations. The results are not as accurate, however, and leaky hydrant drips may give trouble.

Capacity of Pipes.

Diameter of Pipe. Inches.	Contents of Pipes per Foot of Length.	
	U. S. Gallons.	Cubic Feet.
4	.65	.087
6	1.47	.196
8	2.62	.349
10	4.08	.545
12	5.87	.785

If water is used from the pipes for drinking, caustic should be used with caution, all drinking connections being shut while the test is being made, and the pipes carefully flushed before they are opened.

Several useful modifications suggested by Mr. C. W. Mowry, M. E., of the Inspection Department, who has had much experience in the use of the method, have been embodied in the above.

DISCUSSION.

Mr. Allen Hazen.* *Mr. President,* — The method is certainly an interesting and promising one. It would seem that in following it out the fact that the flow of water is not uniform through the section of the pipe would be a matter that would have to be taken into account. The flow in the center of the pipe is always more rapid than it is along the sides, and there is a great deal of mixing. We know from many experiments that coloring matter or any chemical solution will appear at the end of a pipe before anything like a hundred per cent. of the water in it has been displaced.

Mr. R. C. P. Coggeshall.† *Mr. President,* — The process that Mr. Hoxie suggests might be admirable in our large mill yards where the water in the hydrant and sprinkler system remains dormant, and yet perhaps it might not work in a city supply. How is that, Mr. Hoxie?

Mr. Hoxie. It would be absolutely necessary to shut off all flow except that from the leak.

Mr. George A. Stacy.‡ I have had a few leaks to locate. I had one on a broken 16-in. main when there was three feet of frost in the ground. It was on a level place and the street was flooded with two to six inches of water by the time we got the water shut off. We tried to locate the break by walking along on top of the trench over the pipe expecting to find a hole, but we did not find anything on the surface. This was quite a mystery until I found a culvert that extended across the street perhaps 40 ft. on one side of the pipe line and 25 or 30 the other, and only a

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*Civil Engineer, New York City.

†Superintendent Water Works, New Bedford, Mass.

‡Superintendent Water Works, Marlboro, Mass.

few inches deep, being nearly filled up. The water escaped along the pipe line to the culvert and was forced up through the grating. It seemed a tough problem at first to locate the leak. It was evident that it was either one side or the other of the culvert; how far away I did not know. So I sent for men and drills and we drilled down through the frost a certain distance from the culvert, and when we struck dry ground we tried at the same distance the other side, and we kept dividing up the distance between the last hole and the culvert until we found it, after about one hour and a half's work.

The smaller leaks of course are those that stump us the most to find, and any method that will make that easy for us, so that we can make a better account of the water delivered, will be of great benefit to all. There is no particular investigation that I have made. I feel as though we are full as good as the average, and that the results would not pay for any large expense in looking for leaks. Our ground is about all hard pan, and the few brook crossings are always open for inspection.

Mr. Hawley.* *Mr. President,* — Mr. Stacy's remarks remind me of an experience I had some years ago where we found that there was a leak in a crossing under a good-sized stream at a time when there was a considerable flow of roily water in that stream. It was necessary to build a cofferdam, but we did not know where the pipe was broken. So we put a corporation cock in the main, and got a bottle of ordinary washing bluing and put that in, and then turned on the water. It didn't take very long to find where the leak was out in the stream through the change of color when the bluing came out of the hole in the pipe.

Mr. Patrick Gear.† Before the Holyoke water works became a municipal department it was owned by a private corporation, which had cement mains going through some of the streets; but since the municipal department got hold of it they abandoned those cement pipes, but all the connections from them going into the different buildings were left in the ground. One consumer thought he would increase the amount of the water he was getting in his building by hitching on to one of these abandoned services;

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*Chief engineer, Pennsylvania Water Company, Wilkinsburg, Pa.
†Superintendent Water Works, Holyoke, Mass.

instead of increasing the supply, the water simply ran back into the old main and showed up on the street. It would come up in John Jones' cellar to-day, and we would dig around there for two or three days, weather down below zero, until we would strike the old pipe, which we would plug up and wait for developments the next day. Now, in plugging up that pipe and trying to find that leak it occurred to me that the engineers of the water departments of the country, while they can overcome big problems, cannot get as near as the engineers in the telephone system.

Last year I broke a telephone wire, and one of the repair gang went up the pole and telephoned to Springfield, twelve miles away. They told him he was still half a mile from the trouble, and he went along about that distance and found it. To be exact, it was just 2,800 ft. If when we have a break in a pipe and we go into the house and hear the noise in the pipe, the water-works engineer could find some way that would tell us how far away the break was, we would be all right.

But coming back to the cement pipe that we had the trouble with; we were digging down there for a long time and Mr. Tighe suggested that we start at both ends of it. So we plugged the pipe and waited for developments. It would come up in John Smith's cellar the next day, and we would go and plug that up; and we were at it until we had gone through the street and all the cross streets connected with it. Finally we located the connection in an old printing establishment where they wanted water for printing presses.

We had a leak show up at the toe of an earthen dam that we built up there ten or fifteen years ago. There was some question whether it was in the pipe or in the dam. When we were building this dam we laid some 24-in. pipe through it, and we didn't want to put concrete all round the pipe, — that was too much expense,— so we built a couple of piers under our pipe; and in the course of a few years the pipe cracked where those piers were. There was a nice leak there that we discovered by shutting the gates on both sides of it. We dug down 30 or 40 feet and put concrete under the pipes, and they are all right now.

We have some canals in Holyoke; three or four of them run

through the city, and we have had to run pipes over them and under them, and duck them every way, and we have leaks in those canals once in a while. When you get three or four feet of ice in the canal, and your pressure gage in the office shows that you are losing water, you have to take the gang out and have them go to all those gates as they cross the canal and locate the trouble. Where it isn't deep you have to have a man see if there is any bubbling in the water; and he will generally find it in the last one he tries.

Mr. Hoxie. Mr. Hazen's remarks undoubtedly apply to pipes with considerable velocity of flow. With leaks of such magnitude a method such as that described would not often be required, as shown by the experiences just given by several gentlemen. The most troublesome leaks are those from 5 to 50 gallons per minute. This method has been successfully used by our engineers in locating a dozen or more leaks within the last few years, showing that irregularities and velocity are of little importance within the range of its greatest usefulness.

THE CITY TUNNEL AND CONDUITS OF THE CATSKILL AQUEDUCT.

BY WALTER E. SPEAR, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY, CITY OF NEW YORK.

[*Read September 11, 1913.*]

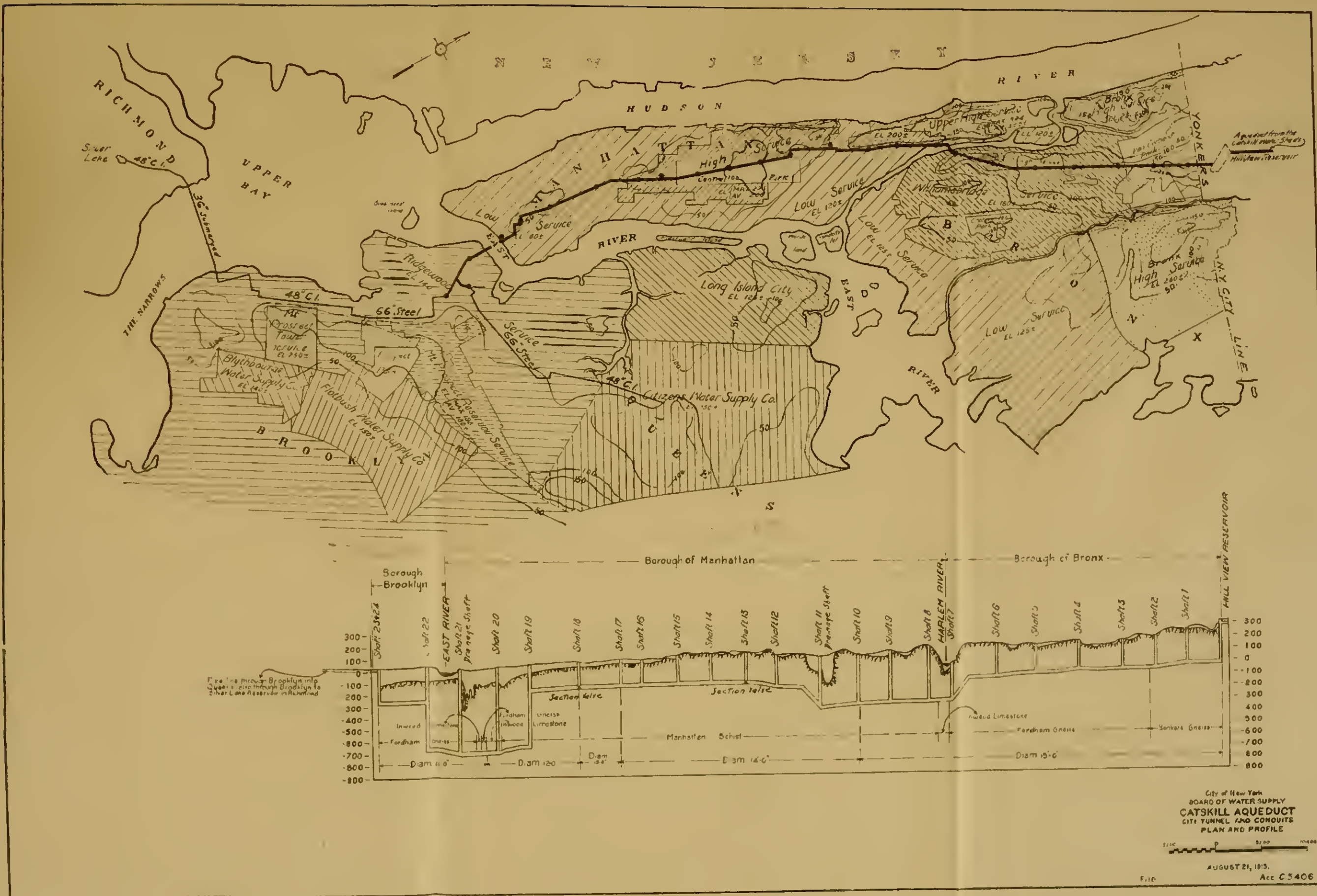
By reason of the peculiar topography of New York City and the extent to which the subsurface space in the older business and residential streets of Manhattan and Brooklyn boroughs is already occupied, the delivery of the new Catskill supply to the great centers of population in these boroughs, as well as to the widely separated suburban sections of the city, presented a most unusual problem. Its solution made by the Board of Water Supply in the large pressure tunnel nearly 18 miles in length, which is being constructed in the bed rock through the heart of the city, is unique in waterworks construction.

As this problem of distributing the Catskill supply was approached, it was at once seen that the task of finding sufficient room in the older streets of the city for the number of 48-in. and 66-in. mains necessary to carry 500 million gallons of water per day with a reasonable loss of head was quite impossible, and larger pipes could not be considered. The streets in which many of these trunk mains would necessarily have to be laid were already occupied by sewers, pipes, and ducts, including the large trunk mains of the present water-supply system, which in Manhattan Borough must to a large extent be reserved for the delivery of the Croton supply to the lower portions of the borough; the existing subways also interposed an effective barrier to the laying of large water mains, and the new subways were laid out in many of the streets in which it would be necessary to place the large conduits for the transportation of the Catskill supply. Aside from these physical difficulties and the great inconvenience and loss which the public would suffer from constructing these mains in the streets, the expense of delivering the Catskill supply in steel or cast-iron mains was found to be excessive, and another solution had to be found.

The brick-lined pressure tunnel, which was built twenty-five years ago as a part of the New Croton Aqueduct from Van Cortlandt Park to Amsterdam Avenue and 135th Street in Manhattan Borough, had already demonstrated the possibilities of deep rock tunnels for the transportation of water in the city, and the successful concrete-lined pressure tunnels more recently constructed outside of the city as a part of the Catskill Aqueduct, pointed the way to a solution of this problem of delivering the Catskill supply to New York City. It was readily demonstrated that such a tunnel, with frequent outlets, having a capacity equivalent to the full yield of the Catskill sources, could be carried deep in the bed rock under the city from the new Hill View reservoir in Yonkers, through the boroughs of The Bronx and Manhattan to the borough of Brooklyn, at half the expense of laying an equivalent number of cast-iron or steel mains, and that this tunnel was in every way superior to a system of pipes in the streets.

DESCRIPTION OF TUNNEL.

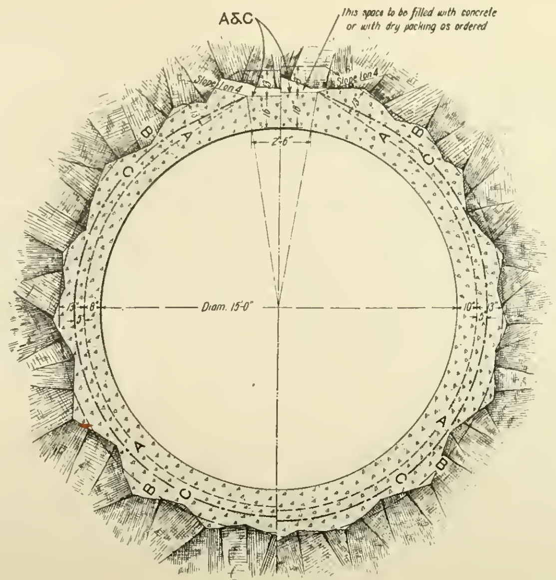
The general alignment and depth of the city tunnel, as the tunnel portion of the Catskill Aqueduct in the city is termed, is seen in Plate XVII. It may be noted that the line is located on the highest ground in the boroughs of The Bronx and Manhattan and crosses the East River at the southerly end of Manhattan Island to the downtown business section of Brooklyn, passing through many of the high-service districts and reaching the centers of population and the great business districts where the greatest consumption exists and the highest pressures must be maintained. The tunnel has a length within the city of 17.7 miles, and is entirely under public waterways, parks, and streets except for 1 027 ft., or 1.1 per cent. of the total length, in which easements over private land had to be secured. All but four of the shafts are likewise located in parks or streets, so that but little real estate had to be acquired by the city for the project. The depth of the tunnel for fully half its length is seen in the profile to be about 200 ft. below the surface, but in order to keep the tunnel in bed rock south of the Harlem River, on the lower east side of Manhattan Borough and in Brooklyn, the grade was fixed at greater depths, as will be later explained. Unlike the pressure tunnels previously


HUDSON RIVER
NEW JERSEY
RICHMOND
UPPER BAY
THE NARROWS
EAST RIVER
BROOKLYN
QUEENS
BRONX
YONKERS
N.Y. CITY LINE
Low Service
High Service
Upper High Service
Ridgewood
Long Island City
Citizens Water Supply Co.
Flatbush Water Supply Co.
Blythbourne Water Supply Co.
Mt. Prospect Tower
48" C.I.
66" Steel
36" Submerged
Borough of Manhattan
Borough of Bronx
Borough Brooklyn
HARLEM RIVER
HILL VIEW RESERVOIR
Manhattan Schist
Fordham Gneiss
Yonkers Gneiss
Diam 11'-0"
Diam 12'-0"
Diam 14'-0"
Diam 15'-0"
City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
CITY TUNNEL AND CONDUITS
PLAN AND PROFILE
AUGUST 21, 1913.

constructed, the city tunnel is to perform the functions of a trunk distribution main. It is not to be simply an aqueduct delivering its entire flow to some objective point, since this tunnel is to have waterway shafts at intervals of about three fourths of a mile, through which water in large volumes may be discharged directly into the distribution mains.

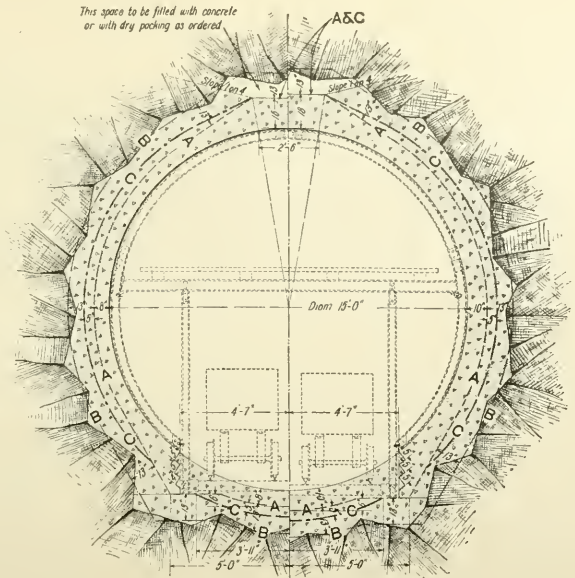
Because of the draft from the tunnel through these shafts it is not necessary to provide for the entire tunnel a capacity equivalent to the full flow of the Catskill Aqueduct, and a successive reduction in size is accordingly made at several points in Manhattan Borough. The tunnel has a finished diameter of 15 ft. for the first 7.7 miles from Hill View reservoir as far as Shaft 10, in St. Nicholas Park, at 135th Street; 14 ft. for the next 5.0 miles to Shaft 17, in Bryant Park, at 41st Street; 13 ft. as far as Shaft 18, at Broadway and 24th Street, a further distance of 0.9 mile; and 12 ft. for 2.0 miles further to a point near Orchard and Hester streets, 1 500 ft. south of Shaft 20. Beyond this point the remainder of the main tunnel leading to the terminal shaft, No. 23, at Flatbush Avenue and Schermerhorn Street, Brooklyn, and the branch to Shaft 24, in Fort Greene Park, having a total length of 2.5 miles, has a diameter of only 11 ft. A section of the 15-ft. tunnel is seen in Fig. 1. This is typical of the other tunnel sections and shows the amount of excavation and the thickness of the concrete masonry lining. A minimum thickness of concrete of 10 in., within which no rock is allowed, has been provided, but the effective thickness inside of any considerable area of rock is 15 in. As a result of the generally wide breakage in the city tunnel, however, the actual thickness of the lining will average fully 23 in.; that is, out to the "B" line, shown on the cross-section, to which payment for excavation and concrete is made. In sections where much seepage through the rock occurs the tunnel is excavated even wider, and a thicker lining provided to resist grouting pressures and insure water-tight work.

Of the 24 shafts through which the tunnel is being constructed, 22 of them are to be finished as waterways; No. 1, the first within the city limits, is to be filled upon the completion of the tunnel; and No. 11 is to be a drainage shaft through which the northerly half of the tunnel may be unwatered. Provisions for draining the



8" TO "A LINE"   10" TO "A LINE"

TYPE A



8" TO "A LINE"   10" TO "A LINE"

TYPE B

QUANTITIES PER LINEAR FOOT / HYDRAULIC ELEMENTS

	Type A		Type B			
	8" to "A line"	10" to "A line"	8" to "A line"	10" to "A line"		
Excavation cu. yds.	10.1267	10.4912	10.3381	10.6952	Area of waterway	176.71 sq. ft.
Concrete " "	3.3961	3.7583	3.6075	3.9623	Wetted perimeter	47.12 ft.
Dry packing " "	0.1856	0.1879	0.1856	0.1879	Hydraulic radius	3.75 ft.

Excavation, masonry and packing quantities computed to ideal average line of excavation, i.e. "B line"

City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
PRESSURE TUNNEL
TYPES A AND B, 15'-0" DIAMETER

1 0 1 2 3 4 5 ft
10 0 40 80 120 160 cm

FEBRUARY 24, 1910.
File Cont-5432C   Acc-10339

Thos. H. Wiggin, Designing Eng.

Alfred D. Flinn, Dept Eng Hdqrs

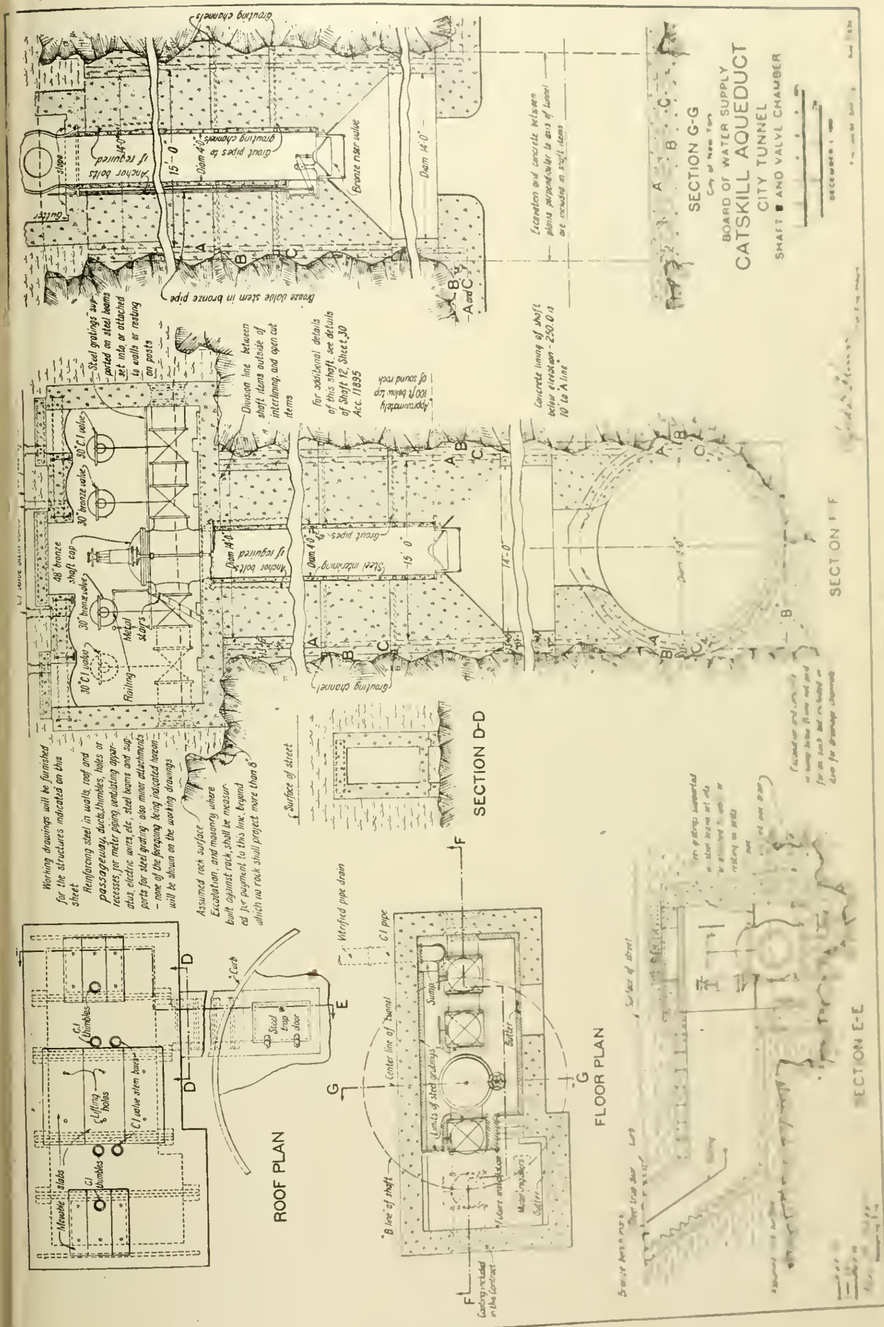

ROOF PLAN
FLOOR PLAN
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
CITY TUNNEL
SHAFT AND VALVE CHAMBER
Working drawings will be furnished for the structures indicated on this sheet
Assumed rock surface
Surface of street
Vitrified pipe drain
Center line of tunnel
Limits of steel gratings
Sump
Steel trap door
Curb
Lifting holes
Movable slabs
C.I. thimbles
48" bronze shaft cap
30" bronze valve
30" C.I. valve
Metal stairs
Railing
Anchor bolts if required
Diam. 14'-0"
Diam. 4'-0"
Grout pipes
Grouting channels
Bronze riser valve
Bronze valve stem in bronze pipe
Steel interlining
For additional details of this shaft, see details of Shaft 12, Sheet 30 Acc. 11895
Concrete lining of shaft below elevation -250.0 is 10" to "A line"

Fig. 2

southerly half of the tunnel are being made at Shaft 21, but this shaft is also to have a waterway.

One of the most interesting features of the city tunnel is the design of these waterway shafts, a typical section of which is shown in Fig. 2. The diameter inside of the outer lining of concrete masonry is 14 ft., and the minimum thickness of lining to the "A" line from 8 to 10 in. The shafts with the largest waterways, Nos. 3, 23, and 24, have diameters about 2 ft. greater than here shown, and the drainage shafts, Nos. 11 and 21, are excavated equally large to provide for a double lining separated by tiling to carry off seepage. From a point 100 ft. below the rock surface, the section of the shaft is to be constructed to a diameter of only 4 ft. within a concrete-lined steel riser pipe, solidly concreted into the shaft. This riser is to be capped at the top, within the large masonry valve chamber just below the surface of the ground, by a bronze tee having two 30-in. outlets, to each of which are to be attached in tandem two gate valves, one a bronze-mounted service valve and another of solid bronze placed next to the tee. The latter valve, which may be closed in the valve chamber or from the surface above the chamber, is intended to be used when the service valve is out of order. At most of the shafts, on by-passes about the service valves, regulating valves are to be installed by which the pressure on the distribution side may be controlled to meet the service requirements.

In addition to these valves at the top of the riser pipe, an emergency valve of the needle valve pattern is to be provided in the shaft of the foot of the riser, which is designed to automatically close when the discharge through the riser exceeds a certain velocity, and which can also be closed by hand either from the chamber or from a control on the surface at some distance from the shaft. All but three shafts are of the circular type just described, though some have two risers of the same size instead of one. Of these exceptions, Shaft 21, the drainage shaft, is approximately egg-shaped, to include both the 14-ft. drainage well and the standard 48-in. waterway; and Shafts 13 and 18, which are section valve shafts, are roughly rectangular to provide space for a well over the section valve in the tunnel and for two 48-in. waterways, taking out of the tunnel on either side of the section valve. Note in

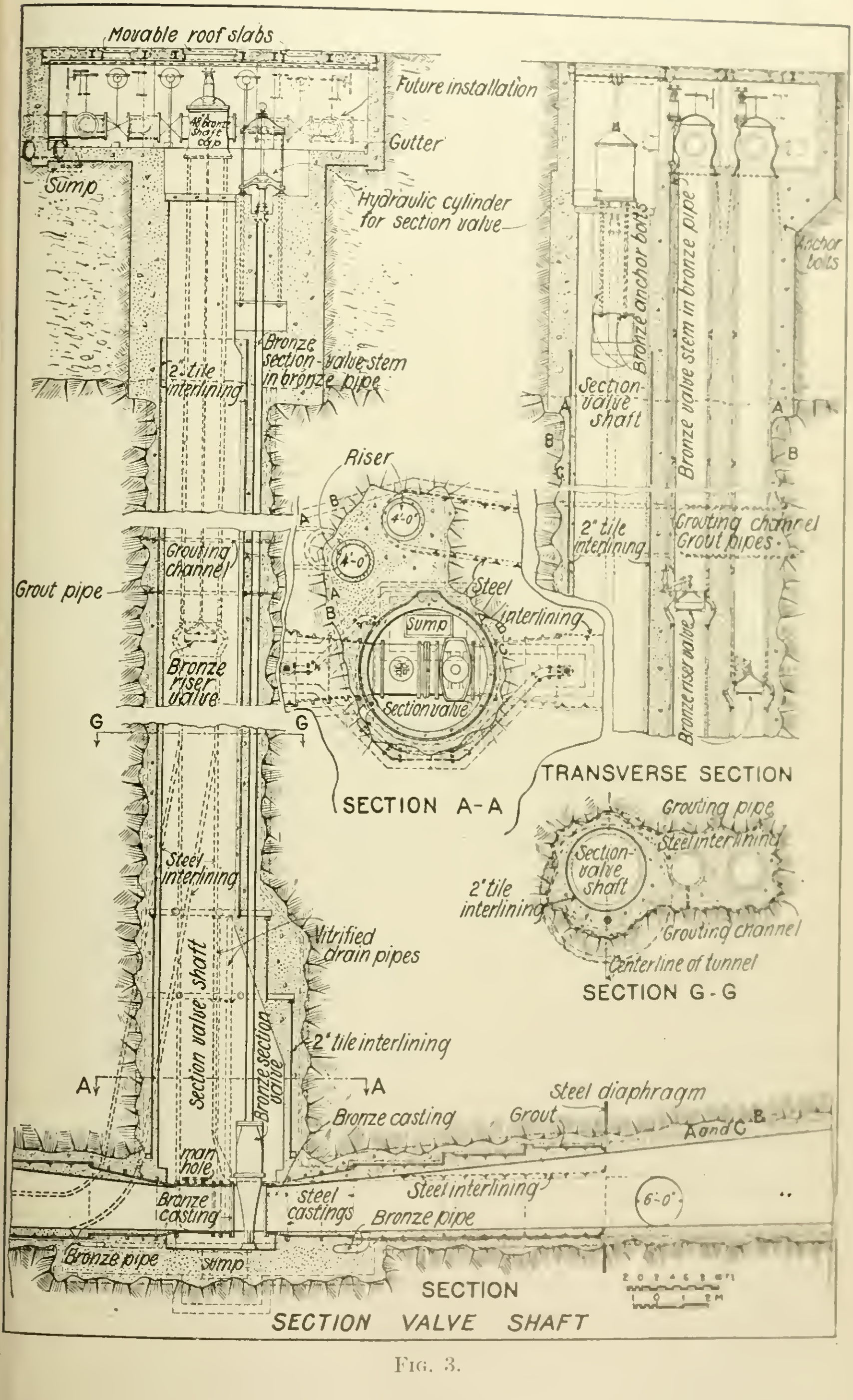

Movable roof slabs
Future installation
Gutter
Sump
Hydraulic cylinder for section valve
Bronze section-valve stem in bronze pipe
2" tile interlining
Grouting channel
Grout pipe
Bronze riser valve
Steel interlining
Vitrified drain pipes
2" tile interlining
Section valve shaft
Bronze section valve
Bronze casting
man hole
Bronze casting
steel castings
Bronze pipe
Bronze pipe
sump
Steel interlining
Steel diaphragm
Grout
A and C
Riser
4'-0"
4'-0"
Steel interlining
Sump
Section valve
SECTION A-A
Bronze anchor bolts
Bronze valve stem in bronze pipe
Anchor bolts
Section-valve shaft
2" tile interlining
Grouting channel
Grout pipes
Bronze riser valve
TRANSVERSE SECTION
Grouting pipe
Steel interlining
Section-valve shaft
2" tile interlining
Grouting channel
Centerline of tunnel
SECTION G-G
6'-0"
SECTION
SECTION VALVE SHAFT

FIG. 3.

Fig. 3, which shows the general design of these shafts, that the section valve is to have a clear waterway of 66 in. and that the tunnel is to be contracted on either side to this diameter in long tapered transition sections to minimize the loss of head. The purpose of these section valves is primarily to permit of cutting off and draining the southerly portion of the tunnel south of Shaft 13 or 18 while still operating the northerly portion.

The amount of water delivered to the city is to be measured by a Venturi meter placed in the main tunnel just north of Shaft 2, the first waterway shaft below Hill View reservoir. The throat of the meter is designed to have a diameter of 8.67 ft. with appropriate sections on either side, through which the transition is made from the 15-ft. tunnel section.

PRELIMINARY INVESTIGATIONS.

No project was ever more thoroughly investigated than the city tunnel, and the rapid progress which has been made in driving the tunnel and the freedom from serious difficulties which has been experienced have more than justified the comparatively small expense of the preliminary work; altogether 201 borings, aggregating 46 343 ft., were made and over two years spent on surveys and studies before contracts were finally prepared. In the early stages of the investigations the Board of Water Supply was fortunate in having the services of Dr. Charles P. Berkey, consulting geologist, to whom great credit is due for the success of the undertaking. Dr. Berkey was able, from his intimate knowledge of the geology of the city, to point out the hidden fault lines and foldings in the rock formation where difficulties might be expected in driving a tunnel, so that attention could be given at once to these localities. No lesson was more thoroughly impressed upon the engineers connected with this work than that demonstrated on the city tunnel, as well as on other parts of the Catskill Aqueduct, that economy of time and money was to be secured in locating large engineering structures by securing the best geological advice.

Conditions in New York City are, on the whole, very favorable for a pressure tunnel of the type which is being constructed; but few other large cities are similarly built on the solid rock. From the Yonkers line to the lower portion of Manhattan Island

the rock, comprising the Yonkers and Fordham gneiss and the Manhattan schist formations, is, generally, at or near the surface, and it was possible to place over half the length of the tunnel at a depth of not much over 200 ft. below the surface, a minimum depth of 150 ft. of sound rock over the tunnel being considered essential to obtain good tunneling ground and to insure a maximum of water-tightness in the finished structure, which is to carry an unbalanced head of about 300 ft. In the section of the tunnel, however, from the Harlem River to Morningside Park, it was necessary to go somewhat deeper than 200 ft. in order to secure the requisite depth of rock cover over the tunnel.

The Inwood limestone underlying the Harlem River had been disintegrated and eroded to some depth, and a deep gorge in the bed rock was believed by the geologist to have been plowed by the ice in a weak zone in the Manhattan schist near 125th Street. In this section the tunnel was, therefore, located at a depth of 300 ft. below sea level and in some points over 400 ft. below the surface. A still greater depth was found necessary on the lower east side of Manhattan in passing through Inwood limestone and Fordham gneiss. Much disintegration in these rocks was found by the borings in Hester Street near Seward Park at a depth of 400 ft. to 500 ft., and some depth of decay was developed also on Delancey and Clinton streets, so that it was not considered safe to place the tunnel between the Bowery and the East River at a depth of less than 700 ft. below sea level. In Brooklyn, the grano-diorite intrusion in the Fordham series, which had largely displaced the sedimentary rock, was found to fall off rapidly toward the south and east beyond the corner of Fulton and Flatbush avenues, and the increasing depth of drift over the rock fixed the southerly limits of the tunnel at Shaft 23. A depth of 300 ft. to the tunnel grade was required in Brooklyn to secure the necessary cover of rock at that point.

The borings for the city tunnel were entirely done by contract, and, on the whole, extremely satisfactory work was secured. Both shot and diamond drills were used, though the deeper work was done by the latter. The large shot drill cores, $1\frac{3}{4}$ to 3 in. diameter, were most satisfactory, but difficulty was met in securing a hole sufficiently straight to go much deeper than 200 ft. without

frequent breaking of the drill rods and consequent interruption in the work. The cores from the diamond drill machines were, on the other hand, rather too small, being only $\frac{13}{16}$ to $1\frac{3}{4}$ in. in diameter, and the results in a few instances were perhaps misleading. At the bottom of the deeper holes on the lower east side, where most of the boring with diamond drills was done, and where depths of 750 ft. were secured, sometimes only a small percentage of the rock penetrated was cored. Besides the handicap of the small size of the core barrel, the failure to secure a greater amount of core in these deep holes was due in some measure to the structure of the rock, which was not strongly cemented together and was tilted up at a high angle, and occasionally to the drill rods supporting the core barrel becoming slightly bent.

CONSTRUCTION.

Contracts for the city tunnel were let in four sections and work begun in June, 1911, and it is expected that the entire work will be completed on schedule time ready for the delivery of water into the city's mains by the latter part of 1915. At the present time, after twenty-six months' work, the city tunnel is 65 per cent. completed; 95 per cent. has been excavated and 20 per cent. lined. One of the four sections of the tunnel is now so far advanced that it will be substantially completed inside of six months.

No great delay was experienced in starting the excavation of the shafts in rock except on the southerly section, where the rock surface is too far below the ground surface to permit of excavating through the drift by other than pneumatic methods. Reinforced concrete caissons 15.3 to 18.0 ft. in interior diameter, with walls 2 to 3 ft. in thickness, were sunk to rock and tightly sealed. Some idea of these caissons may be gained from Plate XVIII. The photograph was taken of the deepest caisson of Shaft 23 when there was about 40 ft. of the caisson below the street surface and some 80 ft. above. Fig. 1 of Plate XIX is a photograph of the caisson at Shaft 24 when being concreted; Fig. 2 shows the bottom of the caisson and the rods to be bent out for the deck. Each of the vertical reinforcing rods shown in this photograph has a turnbuckle at the bottom of the caisson with which it is connected through the sloping face of the V-shaped cutting edge to other

CAISSON AT SHAFT 23.

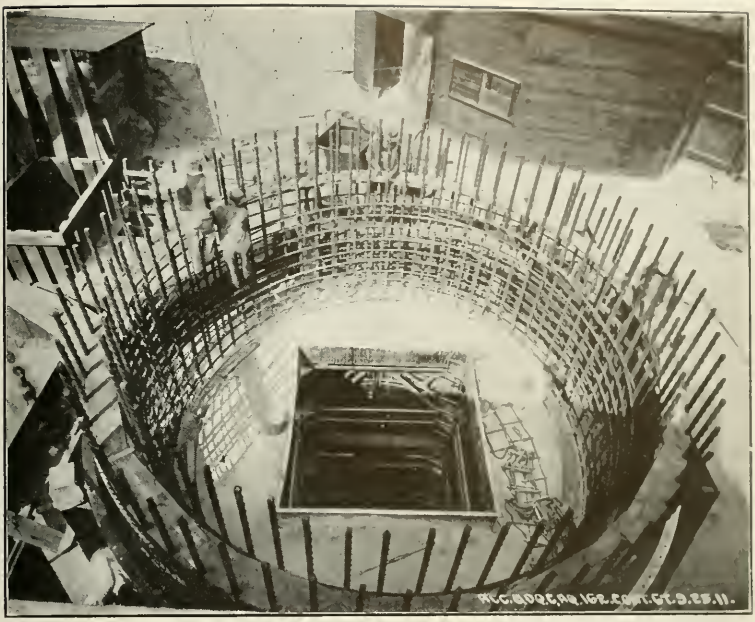


Fig. 1.
Reinforcement of Caisson at Shaft 24.

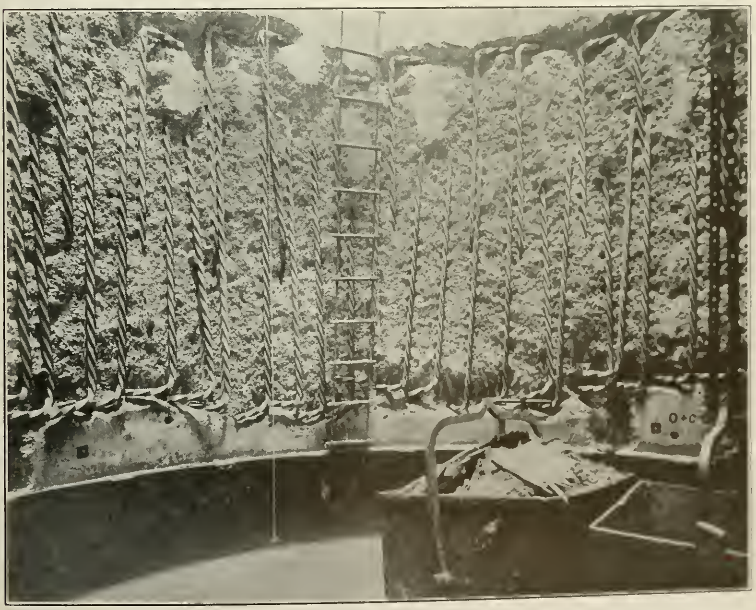


Fig. 2.
Bottom of Caisson.

rods anchored in the concrete of the shaft, well below the surface of the rock. No shaft caisson was sunk at the drainage shaft, No. 21, but four shallow wall caissons enclosing the shaft were put down for the support of the superstructures to be erected over the drainage equipment and the space within them excavated to rock.

From two to three months were consumed in sinking the shaft caissons and in sealing them, from the time the steel shoes were set up in the bottom of the chamber excavation, and maximum air pressures from 17 to 46 lb. per sq. in. were used. So carefully was the work done that no appreciable settlement that could be attributed to the caisson work was observed in the vicinity of the shafts.

The depths of the rock shafts of the city tunnel range from 156 to 714 ft., and, with the exception of the timbered section valve shafts, the outer concrete lining was generally placed in stretches of 100 ft. as the shafts were excavated. From 2.5 to 7.7 months were taken in sinking and lining the shallower shafts in the neighborhood of 200 ft. in depth, and from 6.5 to 12.5 months for the deeper ones, from 250 to 450 ft. in depth. Shaft 21, which has a larger cross-section than the other concrete-lined shafts, and a total depth in rock of 714 ft. to the bottom of the drainage sump, took 14.5 months. The best month's record on all contracts in sinking and lining was 112 ft. at Shaft 20, the average about 50 ft. ranging at the several shafts from 25 to 82 ft.

The first tunnel headings were turned at Shaft 14 in Central Park in December, 1911, and the last at Shaft 21 in February, 1913. At present, 95 per cent. of the entire tunnel has been excavated, leaving less than 5 000 ft. to be driven. The top heading and bench method common in this country has been generally used in excavating the tunnel, and some idea of this work may be had from the photographs in Plate XX. Fig. 1 shows the heading with muck being removed over the bench; Fig. 2 the completely excavated section. Pneumatic drills have been generally employed both in shafts and tunnels, although some extensive trials of electric drills were made by one of the contractors. Except for the northerly section of the tunnel, which is largely in undeveloped sections of the city where a central steam-driven compressor plant could be erected, each shaft, or, in one case in

Central Park, a group of three shafts, was equipped with a compressor plant of 1 to 3 electrically-driven units. All shaft hoists, ventilating fans, and most of the pumps in the tunnel, are also electrically driven as required by one of the clauses of the tunnel contracts, which specifies that so far as practicable, all equipment be driven by electricity to minimize the noise and dust incidental to the operation of steam plants. Among other measures adopted for the safety of the public as well as the workmen in the tunnel was the storage of the explosives at each shaft in a large underground magazine excavated in the rock at tunnel grade and connected with the tunnel by a tortuous drift, driven laterally from a point 100 ft. from the shaft. A heavy steel and timber door, hung in a concrete bulkhead at the entrance to this drift, was designed to protect the workmen from the gases of combustion should an explosion occur in the magazine.

No records in tunnel driving or in shaft sinking have been broken on the city tunnel. The routine and methods usually employed in carrying on mining operations in the country have had, of course, to be materially modified in doing such work in the heart of a large city. The best progress thus far made in excavating the tunnel has been that in the Inwood limestone in the south heading of Shaft 20, where 354 ft. of completely driven tunnel of 11-ft. finished diameter were excavated in one month. The average progress on the several sections has been from 150 ft. to 250 ft. per month, according to the difficulties encountered and the speed which the contractors considered it necessary to push this part of their work.

The lining of the tunnel is well under way on only one section, where six sets of sidewall and arch forms are being concreted from two central mixing plants. On this section nearly 17 000 ft. of lining, or about three quarters of the contract, has been placed. A beginning has been made on the other three sections of the tunnel, but thus far only about 2 000 ft. of lining has been put in.

The methods of concreting in the city tunnel differ little from those which have been developed on other tunnels of the Catskill Aqueduct, though a somewhat richer concrete, mixed in the proportions of 1 of cement to 1½ of sand or screenings and 3 of stone or gravel, is being used in the city. First the concrete of the

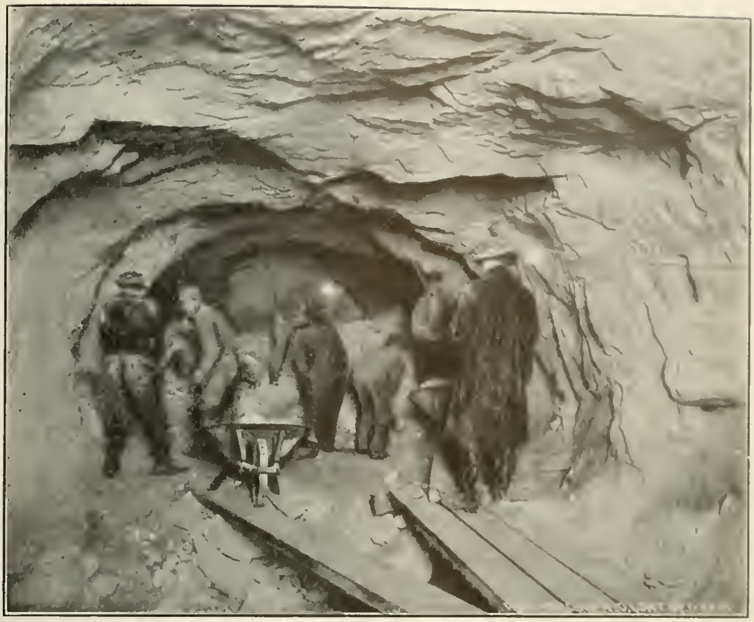


FIG. 1.
REMOVING MUCK FROM THE HEADING.

FIG. 2.
COMPLETELY EXCAVATED TUNNEL.
SHOWING TRACK, AIR PIPES AND ENGINEERS' INSTRUMENT PLATFORM.

invert for a width of 5 to 6 ft. is laid against radial form boards. This part of the concreting goes rapidly, since from 150 to 200 ft. may be readily placed in an eight-hour shift. It is customary to lay all the invert in any section before starting the next operation. After the invert is finished the sidewalls are concreted to the springing line, and finally the arch is placed. The last two operations have come to be done simultaneously, the sidewall being concreted with an adjacent section of arch.

This plan permits the mixing plant to be run at full capacity during the slowest and most difficult part of the concreting, the keying of the arch, the surplus concrete going to the sidewall form. Most of the concrete lining in the city tunnel, thus far put in, has been placed in sidewall and arch forms 60 ft. in length, all in tunnels of 13 and 14 ft. in finished diameter, but forms 80 ft. long are being successfully used in the 12-ft. tunnel. Greater lengths of form are being attempted in the 14- and 15-ft. tunnels, but it has not yet been demonstrated that these forms can be successfully filled at any considerable distance from the mixing plant. The 60-ft. forms are usually concreted every third day, or twice each week, and on the average 1 300 ft. of completed arch and side wall in the 14-ft. tunnel have been concreted each month from one plant with three sets of 60-ft. forms. Metal forms of the "Blaw" type are being used throughout, and very satisfactory work is being secured.

Grouting of one portion of the tunnel north of Shaft 13 will shortly begin. This operation consists of first filling the space over the arch resulting from shrinkage and settlement and the inability of the workmen to quite fill the entire section over the key, and later, of forcing grout under high pressure into the seams and crevices of the rock about the lining through deep-seated pipes placed for this purpose wherever, in the periphery of the tunnel, any water appears.

Besides the tunnel concreting, it has been possible on one section to close up three shafts, Nos. 13, 15, and 16, concrete the risers, and at the last two shafts to build the chambers at the top. The equipment for the shafts and chambers is being delivered and installed. Only about half of the connections to the distribution system will be provided for in the present installation.

COST OF THE TUNNEL.

The city tunnel when completed will have cost in the neighborhood of $20 000 000, including the contracts for equipment, and all real estate, engineering, and other expenses.

Preliminary investigations, surveys, borings, etc.....	$361 300
Real estate..	353 300
Estimated construction, including engineering expenses (approximate)........................	19 500 000
Total	$20 214 600

This amount corresponds to a unit price of $216 per foot of tunnel, and in addition to the tunnel itself includes the cost of over 8 000 ft. of waterway shafts, together with the masonry chambers at the surface and the equipment.

CONDUITS OF THE CITY AQUEDUCT.

Beyond the terminal shafts of the city tunnel, pipe conduits are being laid for the supply of the outlying sections of the city. One of these has already been laid of about equal lengths of 66-in. steel and 48-in. cast-iron pipe from Shaft 23 through Brooklyn borough to the water front at The Narrows in Bay Ridge, a distance of 6.3 miles, and is to be continued 3.3 miles farther across The Narrows to Silver Lake reservoir in Richmond borough, a basin of 400 million gallons capacity recently placed under contract. The connection across The Narrows is to be a 36-in. flexible, jointed pipe laid in a dredged trench with a cover of 8 ft. and placed at no point within the pier head lines less than 45 ft. below mean low water. The main from The Narrows to Silver Lake reservoir is to be a 48-in. cast-iron pipe. From Shaft 24, another conduit, 6.3 miles in length, of 66-in. steel and 48-in. cast-iron pipes, is laid out for the supply of Queens borough, and the cast-iron portion, 4.0 miles long, has already been laid from Broadway and Willoughby Avenue, Brooklyn, to the terminus at Queens Boulevard and Fisk Avenue in Queens borough. Frequent connections are being provided on these conduits by which the existing mains of the distribution system may be fed, and regulating valves are planned for all connections with the low service mains.

The conduits already constructed have presented no difficulties

other than those always met in laying large pipes in city streets, and they merit no further description. The total cost of these trunk conduits in the city, including engineering expenses, is estimated at $2 000 000, and Silver Lake reservoir with real estate and engineering $1 200 000 more.

HYDRAULICS OF THE CITY TUNNEL AND CONDUITS.

It will perhaps be of most interest to water-works men to note the volumes of water which may be drawn from the waterway shafts of the city tunnel, and to outline the possibility in the direction of improving the pressures in the distribution system and of furnishing a gravity supply to the high services of the city with the introduction of the Catskill supply.

In designing the outlets for the waterways of this tunnel, it was, of course, impossible to anticipate with any degree of accuracy the amount of water which in the future it may be desired to draw from each shaft, but so far as possible every reasonable use of the tunnel has been provided for. There are 13 shafts, Nos. 2, 4, 5, 6, 7, 9, 12, 14, 15, 16, 19, 21, and 22, which are to have a single riser 48 in. in diameter, as described in the previous pages, and it is estimated that, in proportion to the effective head between the tunnel and the distribution mains, each waterway of this size can discharge from 50 to 100 million gallons per day with a loss of head in the shaft and connections from 2 to 8 ft. At 6 shafts, Nos. 8, 10, 13, 17, 18, and 20, where greater drafts are anticipated, two 48-in. risers are to be installed, and these can discharge, if required, from 150 to 200 million gallons per day under a loss of head estimated at 5 to 9 ft. Two connections of still larger size, 72 in. in diameter, are to be provided at Shaft 3, at the head of the Jerome Park reservoir, and, when necessary, 300 million gallons per day, more than half of the entire Catskill supply, can be diverted into the Croton system at that point. A similar cross connection with the Croton works is made at Shaft 10, where two 48-in. risers are planned and large pipe connections are to be carried to the 135th Street gate-house on Amsterdam Avenue, from which most of the large mains of the Croton system are laid. A supply of 200 million gallons per day can be delivered to the Croton system at this point. The waterways in the two terminal

shafts, Nos. 23 and 24, have also been made of ample size, since upon these shafts will depend the supply of the three boroughs of Brooklyn, Queens, and Richmond. Each of these shafts is to have two 72-in. risers and can discharge the maximum flow through the 11-ft. tunnel leading to Brooklyn, estimated at 300 million gallons per day with less than 4-ft. loss of head. Regulating valves are to be installed at all shafts except Nos. 2, 8, and 9, which are to supply high-service districts alone, and Nos. 23 and 24, which are to feed the high as well as the low services of Brooklyn, Queens, and Richmond boroughs through the large pipe conduits leading from them.

The actual distribution of the Catskill supply will naturally be decided upon by the Department of Water Supply, Gas, and Electricity, which has charge of the operation and maintenance of the existing water works, including the distribution system. It has been suggested that, with 500 million gallons per day of water available from the Catskill services, it might be the policy of the operating department to furnish the Catskill water to all the high-service districts in the boroughs of Manhattan and The Bronx, and entirely supply the boroughs of Brooklyn, Queens, and Richmond, leaving for the low-service zones in Manhattan and The Bronx the supply from the present sources. This policy would result in great economy to the city, inasmuch as it would permit of supplying the city almost entirely by gravity and of shutting down most of the pumping stations now in operation, including those of the ground-water works on Long Island and Staten Island, until the increase in the consumption of water in the city again required the water from these works. On the basis of some such distribution of the Catskill supply as suggested above, the probable gradient in the city tunnel has been worked out to show what pressures will be available in each section of the city. For this computation a flow equivalent to 575 million gallons per day, or 15 per cent. in excess of the average delivery of 500 million gallons per day, has been assumed for the hours of maximum consumption

The deliveries assumed for each of the tunnel shafts are, of course, purely speculative, as any number of assumptions of this kind can be made, depending upon the future growth and con-

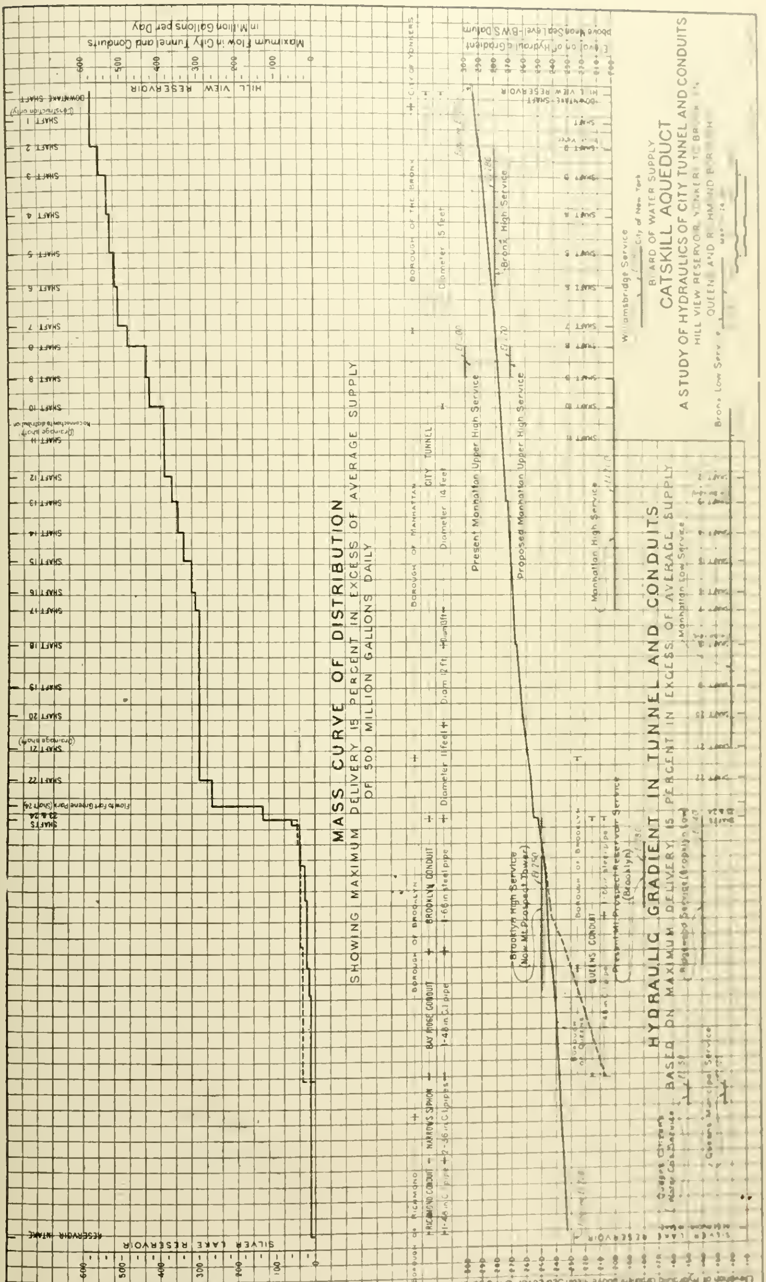

MASS CURVE OF DISTRIBUTION
SHOWING MAXIMUM DELIVERY IS 15 PERCENT IN EXCESS OF AVERAGE SUPPLY
OF 500 MILLION GALLONS DAILY
HYDRAULIC GRADIENT IN TUNNEL AND CONDUITS
BASED ON MAXIMUM DELIVERY IS PERCENT IN EXCESS OF AVERAGE SUPPLY
City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
A STUDY OF HYDRAULICS OF CITY TUNNEL AND CONDUITS
Maximum Flow in City Tunnel and Conduits in Million Gallons per Day
HILL VIEW RESERVOIR
SILVER LAKE RESERVOIR
Present Manhattan Upper High Service
Proposed Manhattan Upper High Service
Manhattan High Service
Brooklyn High Service
CITY TUNNEL
BROOKLYN CONDUIT
QUEENS CONDUIT
NARROWS SIPHON
BAY RIDGE CONDUIT
RICHMOND CONDUIT

FIG. 4.

sumption in each portion of the city, the limits which may be fixed between the various services, and the disposition of the water from the present works. The distribution made gives, however, as severe a test of the capacity of the tunnel as is likely to be made. The assumed discharges from the shafts are shown in the mass curve on Fig. 4, on which is also drawn the corresponding hydraulic gradient in the tunnel and trunk conduits leading therefrom.

The high and Williamsbridge services in The Bronx, the high and the upper high services in Manhattan borough, and a small portion of the low services in these boroughs are provided for in this estimate, and it is assumed that the districts in Brooklyn, Queens, and Richmond now served by the city's water works are entirely supplied. No discharge is assumed for the lower shafts in Manhattan Borough, though some will doubtless be drawn at these shafts for the downtown business districts and ample provision has been made for serving them in constructing the shafts. The effect of diverting to these Manhattan shafts some of the flow estimated for Brooklyn Borough would, of course, result in raising the tunnel gradients above that estimated.

From the diagram it may be seen that on the distribution for the Catskill supply that has been here assumed, the average gradient in the city tunnel between Hill View reservoir and Brooklyn is 2 ft. to a mile. With the water in Hill View reservoir at Elevation 295 (B. W. S. datum, mean sea at Sandy Hook), which is 1 ft. below the normal flow line, the gradient in the tunnel within the borough of the Bronx is from Elevation 280 to Elevation 290, which is quite high enough to supply the high services in that borough, giving an average pressure of about 50 lb. per sq. in. in the Bronx high service, and 70 lb. per sq. in. in the Williamsbridge service.

Similarly, the tunnel gradient in Manhattan varies from Elevation 280 at the Harlem River to about Elevation 260 at the southerly end of the island, which corresponds to a pressure of about 70 lb. per sq. in. in the Manhattan high service and about 40 lb. per sq. in. in most of the Manhattan upper high service. Several acres in the latter district are, however, too high for the tunnel gradient and will have to be supplied by a local "booster" station

or from one of the present pumping stations of the Croton system. In lower Manhattan Borough the estimated tunnel gradient is sufficiently high to raise the water to the sixteenth floor of the higher buildings and to give an average pressure at the curb of about 100 lb. per sq. in.

In Brooklyn Borough the hydraulic gradient is estimated from Elevation 255 to Elevation 260, falling off in the large trunk conduits leading from Shafts 23 and 24 to Elevation 240, within the limits of the borough. This gradient is high enough to deliver water to a level slightly above the present intermediate or Mt. Prospect Reservoir service, giving an average pressure of about 60 lb. per sq. in. in that service, and to supply the high service at a somewhat lower gradient than now, taking care of the entire service with the exception of a few isolated areas, to which it may be necessary to pump. Some reduction in pressure would doubtless be made at the connections with the mains of the low or Ridgwood service.

The gradient estimated in the Queens conduit is ample to supply the districts now occupied in Queens Borough, and the gradient in the conduit to Richmond Borough is sufficiently high to deliver a supply to the new Silver Lake reservoir at Elevation 230, which is intended to serve the entire borough with the exception of the higher hills.

Considering the smooth, even surface which is being secured on the tunnel lining, the value of 120 assumed for "C" in the Chezy formula in working out this gradient is conservative, and it is quite possible with the flows here assumed that for many years the gradient in Brooklyn would at least be 5 or 6 ft. higher than estimated, corresponding to a value of "C" of 130.

Aside from the great economy effected by the tunnel plan and the gain to the city and the public in avoiding the laying of large mains in busy streets of the city, it is evident, from a consideration of the design and construction of the city tunnel and of its possibilities in the direction of improved service, that this tunnel has immeasurable advantages over a system of pipes, in that the tunnel is a permanent structure, not exposed to injury from construction work in the streets, and its capacity is such that it will make available to all sections of the city a continuous supply

of water in large volumes and at ample pressure for fire protection as well as for domestic and industrial uses.

Among the many notable engineering problems that have been worked out on the Catskill Aqueduct under the direction of our president as chief engineer of the Board of Water Supply, not the least in brilliancy of conception and boldness of design is this plan for the distribution of the Catskill water to all parts of New York City.

DISCUSSION.

Mr. Lazarus White.* The chief progress that has been made in this type of construction is due to the improved method of shaft sinking, for the tunnels connect the bottoms of shafts, and they have to be sunk before the tunnels can be started. Five or six years ago sinking shafts was thought to be a very serious matter; and as there had not been deep shafts of this character sunk in this part of the country, there was a great deal of exaggeration as to their cost.

At the time we started to work on the first tunnel of this character on the Catskill Aqueduct, the shafts were all timber-lined, the timber in the waterway shafts being subsequently taken out and concrete lining put in. About that time a method of sinking concrete shafts without the use of timbering came into use in the coal regions and was adopted in the later siphons. In this method the shafts were sunk in stretches of about a hundred feet, and immediately lined with concrete, which protected the sides from caving and subsequently became a waterway. This method proved to be much more economical than taking the timbering out and putting the concrete in, and it was adopted later even in shafts which were not waterway shafts, and shafts which were expected to be in use for only a few years.

Due to the great number which were sunk, considerable improvements were made in the art of shaft sinking, so that these concrete-lined ones were sunk at several times the speed that it was originally supposed could be made. In one case the shaft was sunk 200 ft. and completely lined in less than three months, and in some cases 700 ft. were sunk in about one year, — even

* Division Engineer, Manhattan Division of the Catskill Aqueduct.

where the tops of the shafts had to be started with compressed air caissons.

Besides improvement in speed, another perhaps even greater improvement was originated here in connection with shafts where water was encountered. These had previously proven to be very expensive, for every time work was stopped to blast, the water accumulated and had to be pumped out, making the work very slow and difficult. A method was learned, however, by which the water could be cut off as the shaft went down piecemeal, by lining the shaft with about two feet of concrete and injecting cement grout into water-bearing seams. In this way the shafts were kept practically dry and safe to the bottom, almost regardless of the amount of water encountered. Of course there was some slowing up in progress, but not very much. A concrete-lined shaft can now be sunk, at a rough estimate, for about $200 a foot.

In one of our first timber-lined shafts before this method had been well worked out, there was a great deal of delay caused by encountering quantities of water. One of our contractors said he could have saved several hundred thousand dollars in the sinking of a similar shaft if this method had been known.

When you have overcome the problem of shaft sinking, the rest of it is comparatively simple. You practically make the conditions to suit yourself, by the depth of shaft and by exploring the ground. Pressure tunnels can run up and down at any angle to get from shaft to shaft, and you can pick out the more favorable rocks for tunneling. I believe that this type of construction will be used more and more, particularly where pipe lines under great heads would otherwise be laid. That is, in case of a deep and broad valley these tunnels compare more and more favorably with steel pipe lines.

New York City can fairly claim the credit of originating this type of construction on a modern and large scale. It was first used in the new Croton aqueduct under the Harlem River about thirty years ago. The application of it for distributing water is entirely new; it is the adaptation of a pressure tunnel and a siphon tunnel to the conduit line. It has, I think, worked out wonderfully well.

There has been one case in the West, which you probably recall,

where there was some trouble with a tunnel of this character, but if you will examine that case you will see that that tunnel was a sort of a halfway measure; it was a cross between a steel pipe line and a tunnel of this character. It was started several years ago, when the method had not been well worked out even here. We know very well that the way to cross a valley is not by sinking an incline at each side and then coming out at the bottom, but by sinking vertical shafts and then driving a tunnel nearly horizontally between them. I believe that if that tunnel had been driven in that way they would not have encountered any trouble.

THE ADDITIONAL WATER SUPPLY FOR THE CITY OF PITTSFIELD, MASS.

BY HIRAM A. MILLER, CONSULTING ENGINEER.

[*Read September 10, 1913.*]

EXISTING WATER SUPPLY.

Previous to the construction of the additions to the Pittsfield water supply, to be described in this paper, the water works consisted of a gravity system from four watersheds east of the city in the towns of Dalton, Hinsdale, and Washington; the water being taken from small intake reservoirs on Sackett, Hathaway, Ashley, and Mill brooks. Near the headwaters of Ashley Brook is a natural lake called Ashley Lake, which had been made into a large storage reservoir by the construction of a dam across Ashley Brook, its outlet; but which, on account of its small watershed, if drawn down to the limit of only its gravity capacity, would require two or more years to fill again. The storage from this lake passes down Ashley Brook into the intake reservoir below. (Plate XXI.)

These four intakes are at different heights, the elevation of the overflow varying from Elevation 1249 of the one on Ashley Brook to Elevation 1340 of the one on Mill Brook.

The areas of the different watersheds above the points of taking the water are as follows:

Sackett	1.76 sq. miles
Hathaway	1.05 sq. miles
Ashley, below Ashley Lake	1.75 sq. miles
Ashley Lake Watershed*	.72 sq. miles
Mill	1.77 sq. miles
Total	7.05 sq. miles

The capacities of the reservoirs are as follows:

Sackett	2 000 000 gal.
Hathaway	1 000 000 gal.
Ashley	23 000 000 gal.
Ashley Lake	409 000 000 gal.
Mill	14 000 000 gal.

* Including Ashley Lake.

It was estimated that the available water supply from the above sources in a series of dry years would be 2 650 000 gal. per day.

The supply mains leading into the city consisted of a 12- and 16-in. cast-iron pipe from Ashley intake, with a 10-in. pipe from Hathaway intake and another of the same size from the Sackett intake, joining these pipes. There was also a 12-in. pipe from the Mill Brook intake joining the 12- and 16-in. pipes from Ashley intake near the southerly edge of the settled portion of the city.

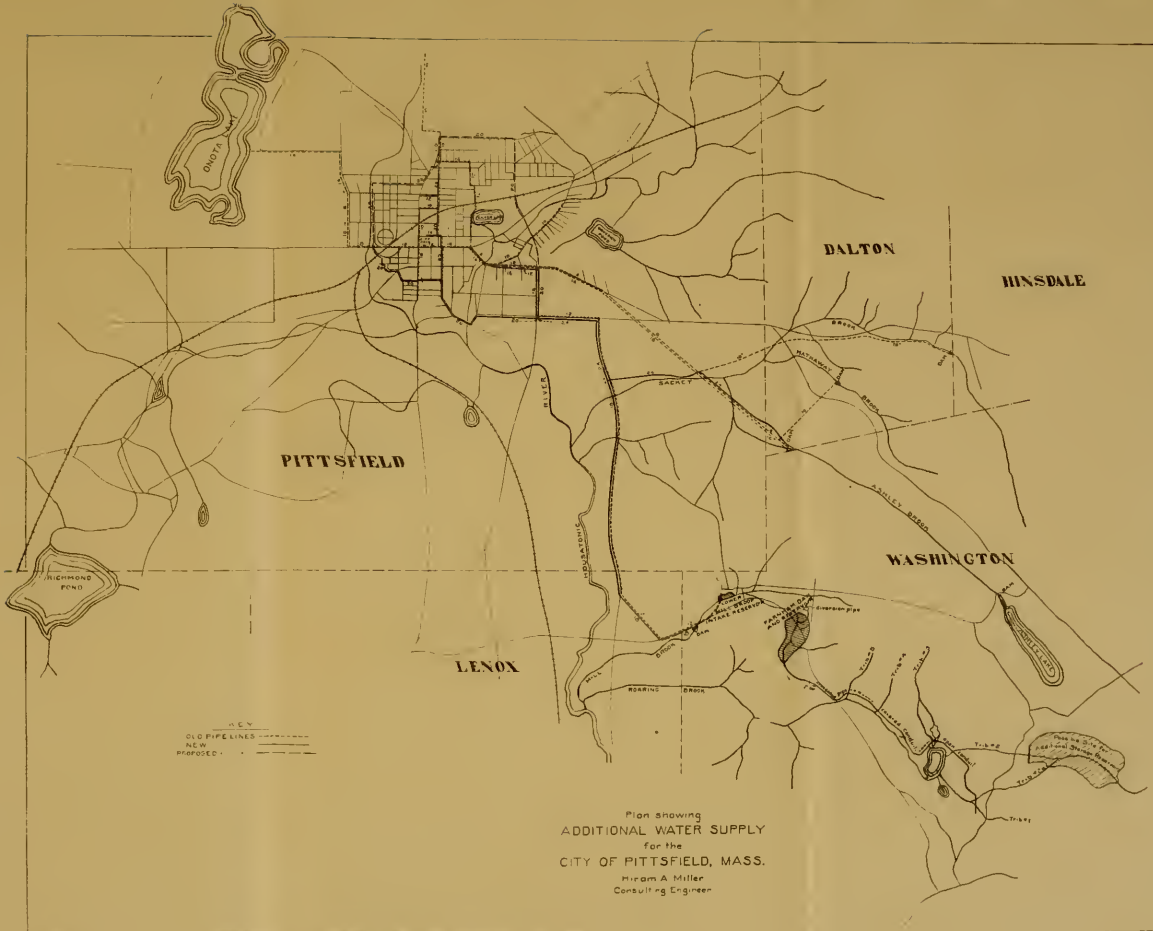
The static pressure at City Hall, with the Ashley intake reservoir full, is 86 lb.

It had been known for some years that the city was rapidly outgrowing its water supply. In 1908 the consumption was estimated to be 2 500 000 gal. per day, and in 1909 it had increased to 2 800 000 gal. per day, notwithstanding the most stringent measures were taken to keep the consumption down. In order to make up for the deficiency of the water supply, a small dam was constructed in the fall of 1908 on Roaring Brook, a stream to the south of Mill Brook, and the water diverted through a wooden flume into the Mill Brook watershed. A pump was also installed at Ashley Lake to pump the water from the lake when the water fell below the level at which it would flow by gravity through the sluice gate in the Ashley Lake dam. In 1909 a pumping station was installed at Onota Lake in the northwestern part of the city, from which water was pumped into the mains. The consent of the State Board of Health to the temporary use of the Onota Lake water had been obtained.

The distributing mains were also small, the largest being 12 in. in diameter, so that pressures generally throughout the city were quite low.

PROPOSED EXTENSIONS.

The only available sources for an additional water supply were Onota Lake referred to above, Richmond Pond southwest of the city, and Roaring Brook above the point where it could be diverted into the Mill Brook watershed. This last-mentioned source of water supply seemed especially desirable as it would be a gravity supply, while the water from the lakes would require pumping, and consequently this source of water supply was decided upon.


ONOTA LAKE
DALTON
HINSDALE
PITTSFIELD
WASHINGTON
LENOX
RICHMOND POND
HOUSATONIC RIVER
SACKET
HATHAWAY BROOK
ASHLEY BROOK
ASHLEY LAKE
MILL BROOK
ROARING BROOK
Diversion pipe
KEY
OLD PIPE LINES
NEW
PROPOSED
Plan showing
ADDITIONAL WATER SUPPLY
for the
CITY OF PITTSFIELD, MASS.
Hiram A Miller
Consulting Engineer

Surveys and investigations of this water supply had been made in 1908 and 1909.

Permission had been obtained from the State Board of Health to use certain tributaries of Roaring Brook for a permanent water supply, as it was deemed undesirable to take the water directly from Roaring Brook, as the water flowed through a large pond, the bottom of which was composed of muck from five to thirty feet deep and was surrounded on all sides by swamp areas, the soil of which was principally muck. Additional supply mains were to be built into the city, and additional distribution mains through the city.

DAM.

It had originally been intended to construct a reservoir with an earth dam on Mill Brook about three thousand feet above the Mill Brook intake, and divert two of the tributaries (No. 4 and No. 5) of Roaring Brook into this reservoir; the reservoir to have a storage of from one hundred fifty to two hundred fifty million gallons; then, later on, to construct an additional storage reservoir on the largest of the tributaries of Roaring Brook, known as tributary No. 2, and divert this tributary and No. 1 and No. 3 into the Mill Brook watershed. Further investigations lead to the conclusion that it would be better to construct a higher dam of masonry and impound a larger quantity of water, particularly as investigations at the site of the proposed reservoir on tributary No. 2 of Roaring Brook showed that two dams would be necessary instead of one, and also that there would be a large area of shallow flowage. It was, therefore, finally decided to erect a dam of cyclopean masonry with concrete blocks on the upstream face (to be called the Farnham Dam, in honor of the engineer of the board of public works of the city) about 100 ft. high above the bed of the brook, with a spillway at Elevation 1585, and the top of the dam at Elevation 1595, impounding, as estimated, 442 000 000 gal., which would at least be nearly as much storage as the area of the watershed tributary to the reservoir would warrant; to construct a diversion conduit along the northeasterly side of Roaring Brook, diverting all five of its tributaries into the Farnham Reservoir; to construct a small diversion conduit from one of the tributaries of Mill Brook

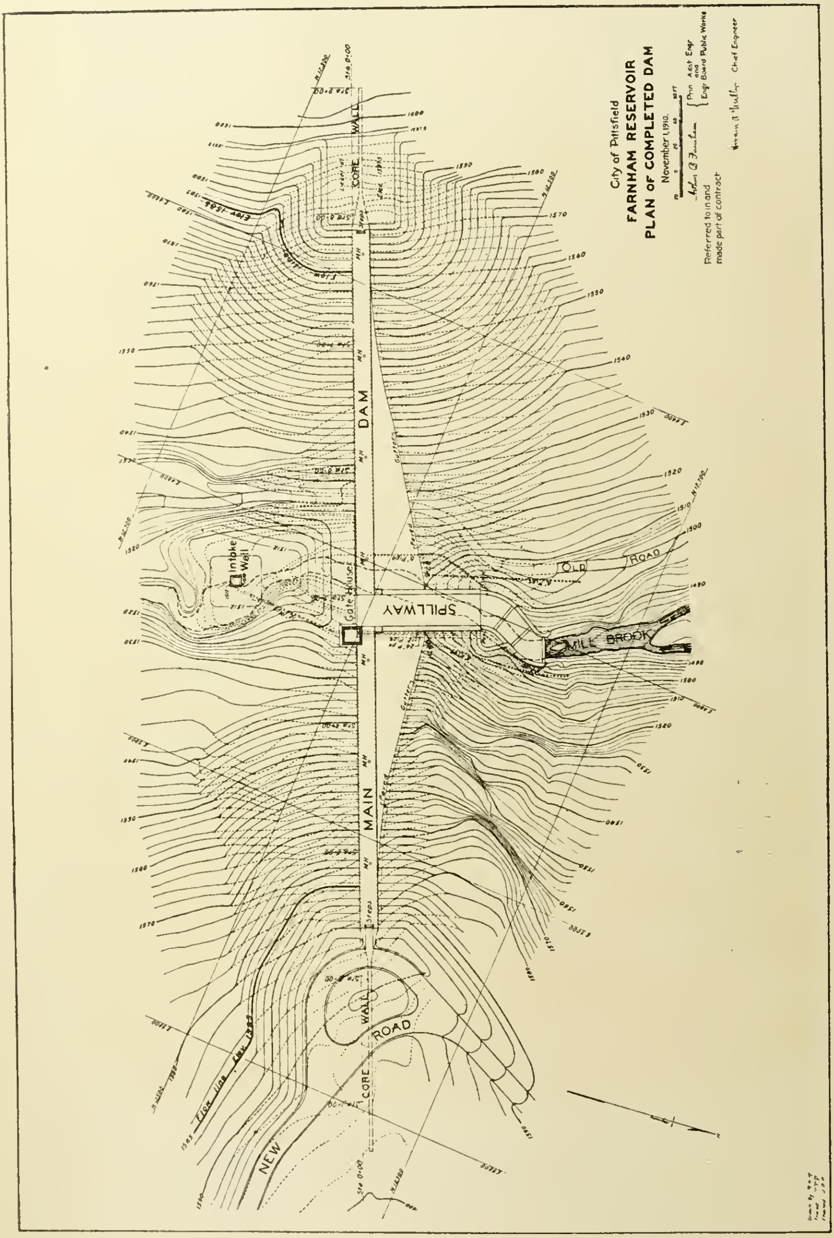
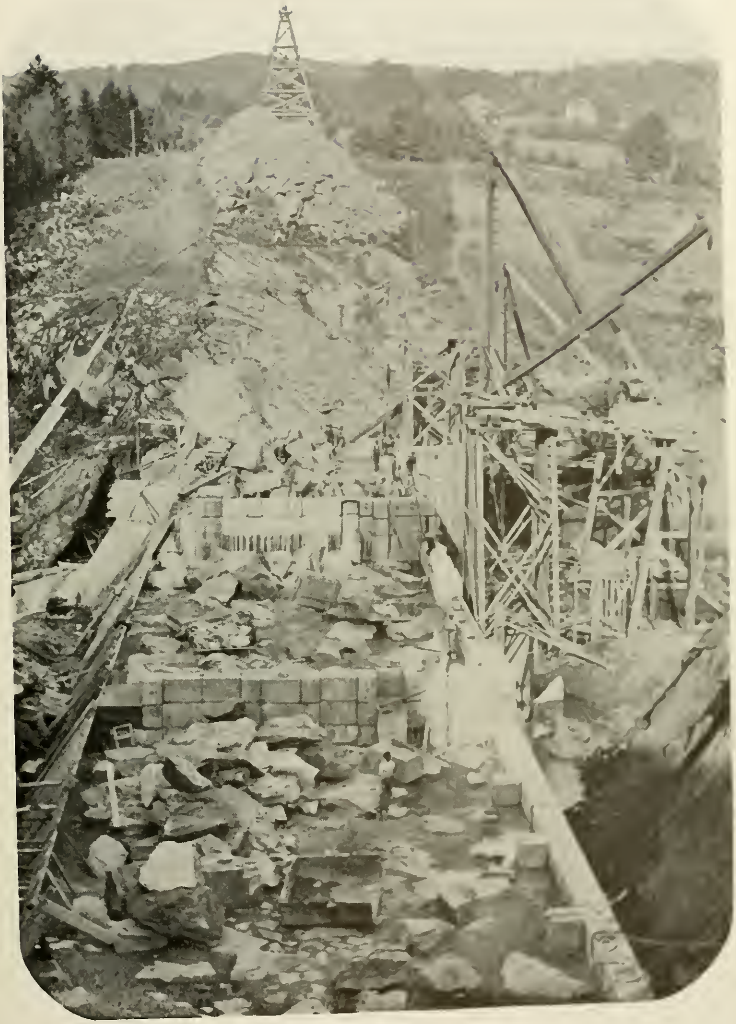

City of Pittsfield
FARNHAM RESERVOIR
PLAN of COMPLETED DAM
November 1, 1910.
Referred to in and made part of contract
Asst. Engr.
Engr. Board Public Works
Chief Engineer
MAIN
DAM
CORE WALL
SPILLWAY
Gate House
Intake Wall
MILL BROOK
OLD ROAD
NEW ROAD
Gutter
Steps

Fig. 1.



DAM UNDER CONSTRUCTION.

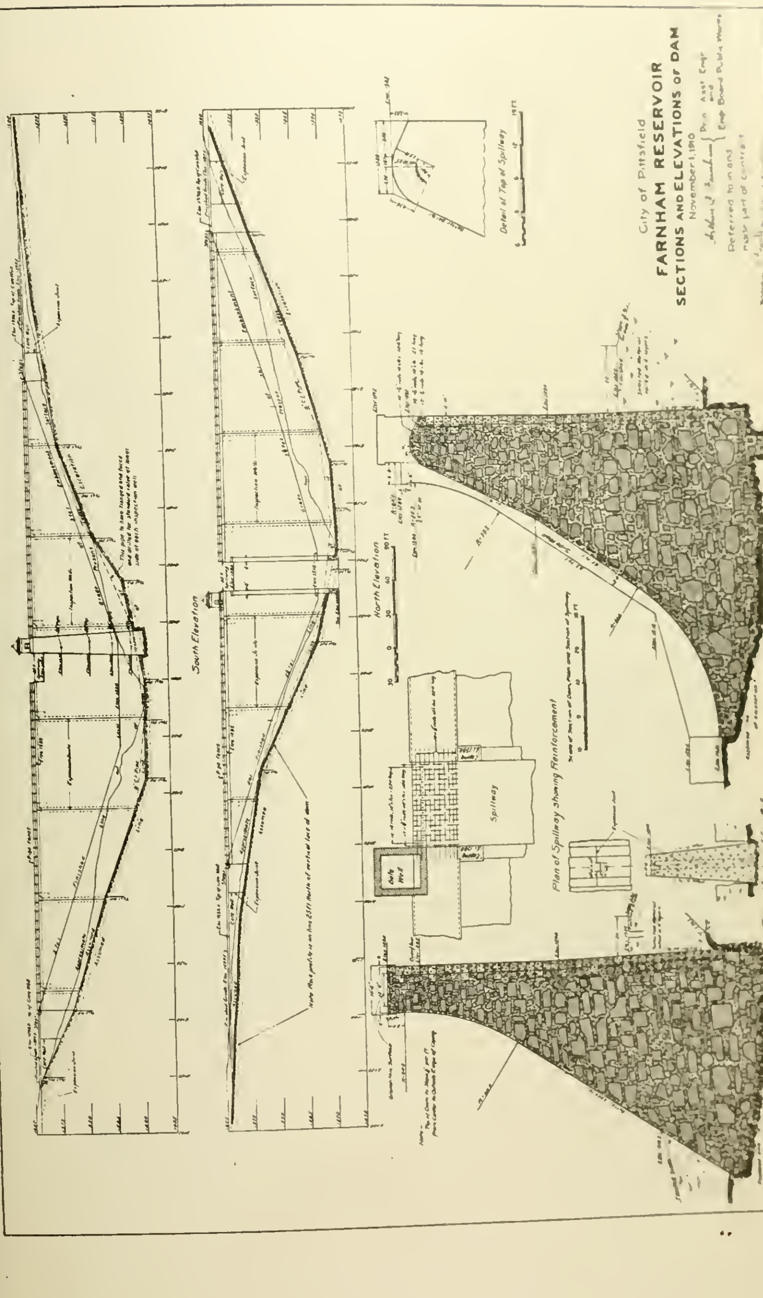

City of Pittsfield
FARNHAM RESERVOIR
SECTIONS AND ELEVATIONS OF DAM
November 1, 1910
South Elevation
North Elevation
Plan of Spillway showing Reinforcement
Detail of Top of Spillway
Spillway
Gate Well

FIG. 2.

into the Farnham Reservoir; and also to construct large supply and distribution mains; leaving further consideration of the reservoir on tributary No. 2 of Roaring Brook until such time as the city would need to investigate farther additions to its water supply.

Test pits and other investigations showed that the foundation of the dam would be mainly rock of an unusually good quality of schist running into Cheshire quartzite at the westerly end of the dam. There was a large outcrop of quartzite a short distance above this end of the dam, so that the cyclopean stones and the coarse aggregates for the masonry would be easily available. It was thought probable that this quartzite could be crushed by sand rolls into material suitable for fine aggregates, or failing in that there were apparently large quantities of sand in the Housatonic Valley about three miles from the site of the dam which appeared to be satisfactory.

The dam has a gravity section, about 600 ft. in length, with core walls at each end, making the total length of the dam about 900 ft. It is divided by expansion joints with inspection wells passing down through the joints, near the upstream side, to the bottom of the dam. These inspection wells are connected at the bottom by cast-iron drainage pipes, with a pipe leading from the bottom of the deepest well to the westerly side of the lower end of the spillway.

The gate well is on the upstream side of the dam outside the regular section, and is about 10 ft. square, having four inlets at various elevations, the lower one consisting of a 12-in. pipe with one gate valve, the others of 20- or 24-in. pipes, having two gate valves on each pipe. On the downstream side of the gate well are one 24- and one 12-in. cast-iron pipe lines leading into a pool on the easterly side of the lower end of the spillway, each having sluice gates in the gate well. The valves and gates are controlled by operating stands in a gate house over the well.

The expansion joints are 80 ft. apart, having 6-in. vertical offsets, 8 ft. apart through the dam. There is a copper strip across the joints on the upstream side of the inspection well similar to the one designed by the engineers of the board of water supply of New York City for the Kensico Dam. One side of the expansion joint is constructed of concrete blocks; on the other side the concrete of the cyclopean masonry is permitted to come to the joint. Be-

DAM.
UPSTREAM VIEW. SPILLWAY AND GATEHOUSE.

fore laying the concrete the side of the joint first constructed was coated with hot tar pitch, then a sheet of roofing paper was applied to the hot pitch, and the roofing paper was again coated with hot pitch.

During the last of February of the present year, after the coldest spell of the winter, when the reservoir was full, the total leakage through the joints measured at the end of the drainage pipe was at the rate of 18 000 gal. per day, which had decreased during the present summer to 200 gal. per day when the reservoir was drawn down 11 or 12 ft. Moisture appears on the downstream side of the dam to the extent that a large proportion of the area appears wet on a damp morning, but in a sunshiny afternoon the surface is mainly dry.

The specifications for the dam provided for three classes of mass concrete, of concrete blocks, and of cyclopean masonry, depending on the mixture of the concrete. Class *A* was concrete consisting of one part cement, two parts fine aggregates, and four parts coarse aggregates, with no stones larger than two inches in their greatest dimension. Class *B* was concrete consisting of one part cement, two and one-half parts fine aggregates, and four and one-half parts coarse aggregates, with no stones larger than two and one-half inches in their greatest dimension. Class *C* was concrete having the materials in the proportion of 1 : 3 : 6, with no stones larger than three inches in their greatest dimension. Class *D* was to have the same proportions as Class *A*, but to have no stones larger than ¾ in. in their greatest dimension.

It was expected that Class *A* concrete would be used in the lower portion of the dam, and in the lower portion of the gate-house; that Class *B* concrete would be used in the main portion of the dam above where the Class *A* concrete was to be used, up to Elevation 1585, the elevation of the spillway; that Class *C* concrete should be used between Elevation 1585 and Elevation 1595, the elevation at the top of the dam, and that Class *D* concrete was to be used for filling spaces around the copper strips in the expansion joints.

It was further specified that the proportion of fine to coarse aggregates in any of the classes of concrete might be varied so as to reduce the voids to a minimum.

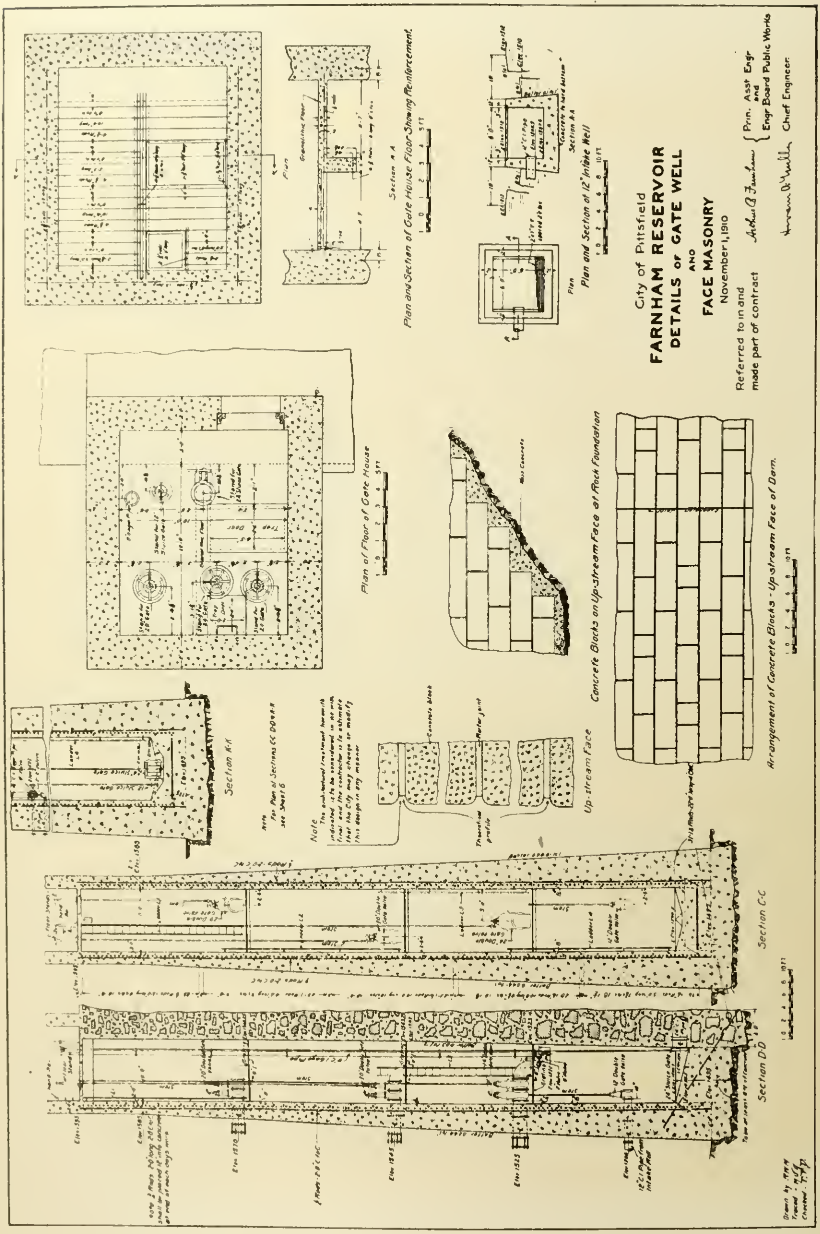

Section D-D
Section C-C
Section K-K
Up-stream Face
Plan of Floor of Gate House
Concrete Blocks on Up-stream Face at Rock Foundation
Arrangement of Concrete Blocks - Upstream Face of Dam.
Plan and Section of Gate House Floor Showing Reinforcement.
Plan and Section of 12" Intake Well
City of Pittsfield
FARNHAM RESERVOIR
DETAILS OF GATE WELL
AND
FACE MASONRY
November 1, 1910
Referred to in and made part of contract
Prin. Asst Engr and Engr Board Public Works
Chief Engineer

FIG. 3.

FIG. 1.
COMPLETED DAM. LOOKING WEST.

FIG. 2.
RESERVOIR PARTLY FULL.

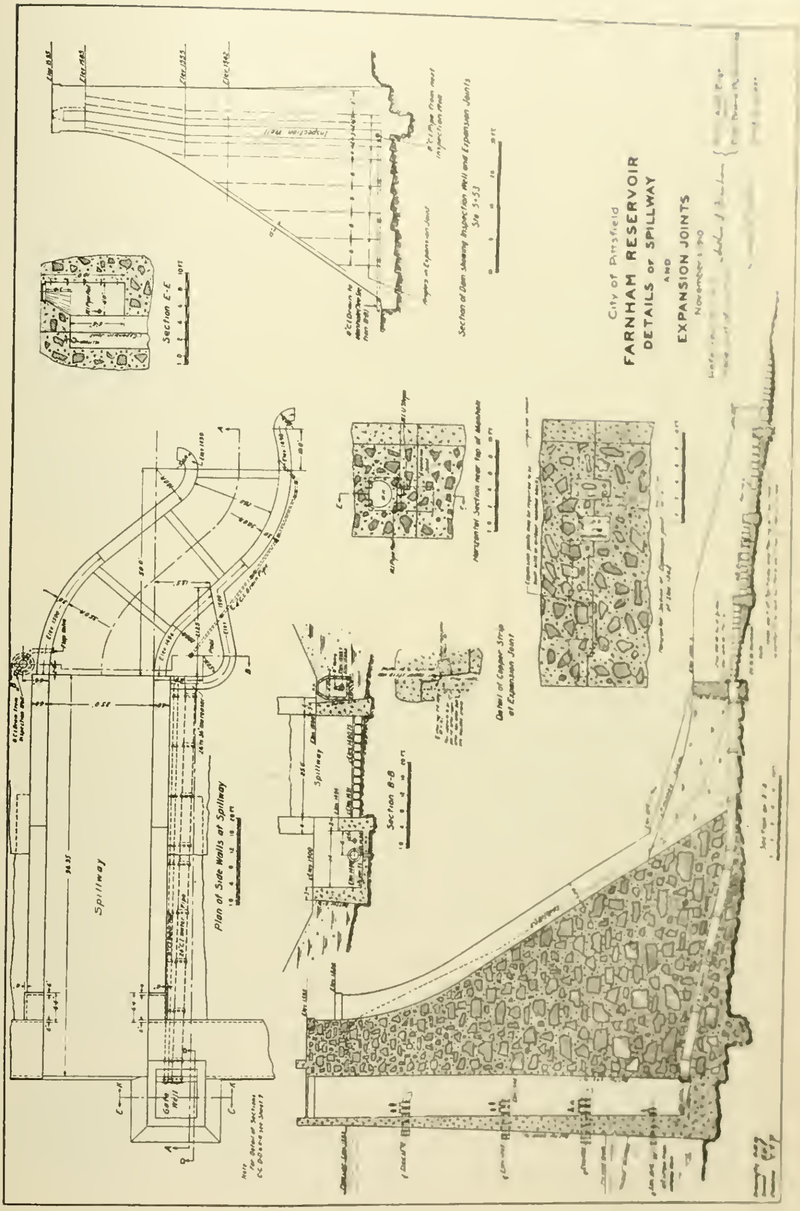

City of Pittsfield
FARNHAM RESERVOIR
DETAILS OF SPILLWAY
AND
EXPANSION JOINTS
Spillway
Plan of Side Walls at Spillway
Section B-B
Section E-E
Inspection Well
Detail of Copper Strip at Expansion Joint
Gate Well

Fig. 4.

The contractor's plant consisted of the usual machinery for quarrying, crushing stone, mixing concrete, placing masonry, and so forth, and had in addition rolls for crushing stone for use in the place of sand for the fine aggregates. The rock from the

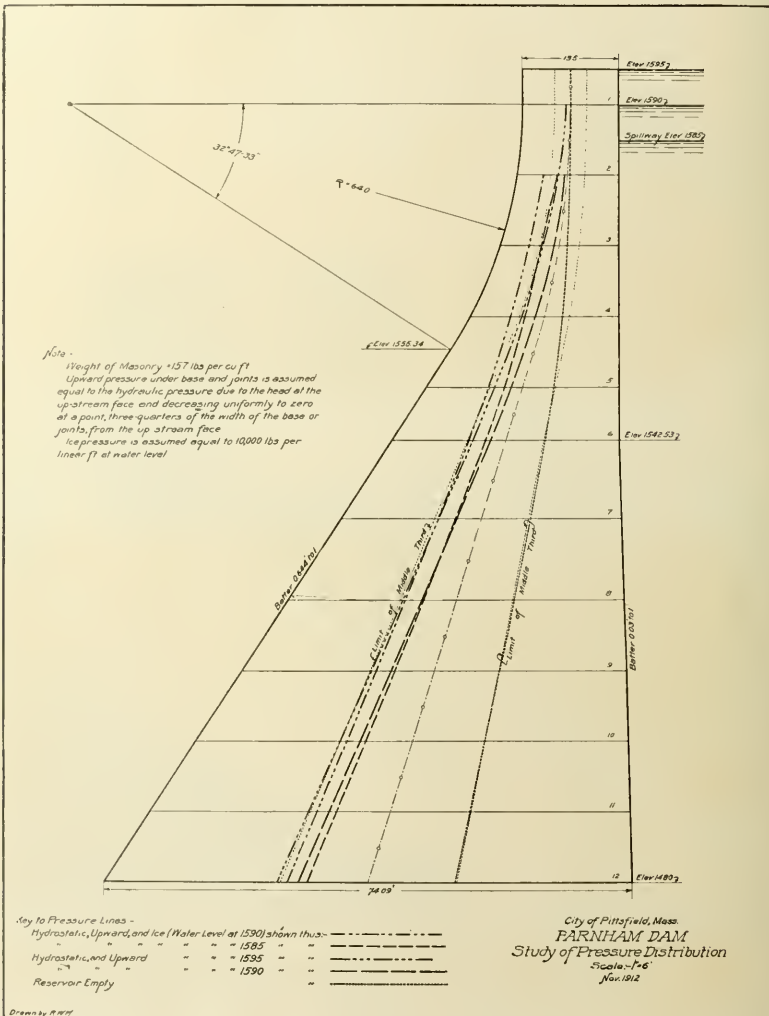


Fig. 5.

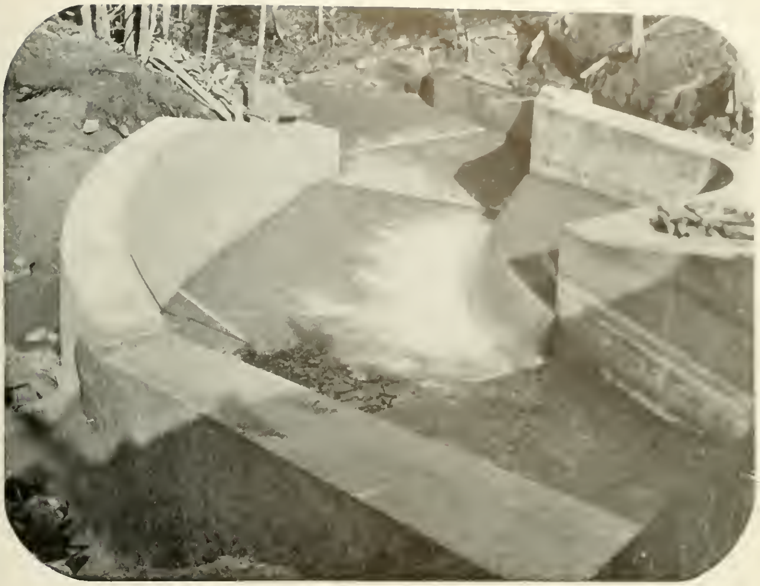


FIG. 1.
SPILLWAY FROM ABOVE.

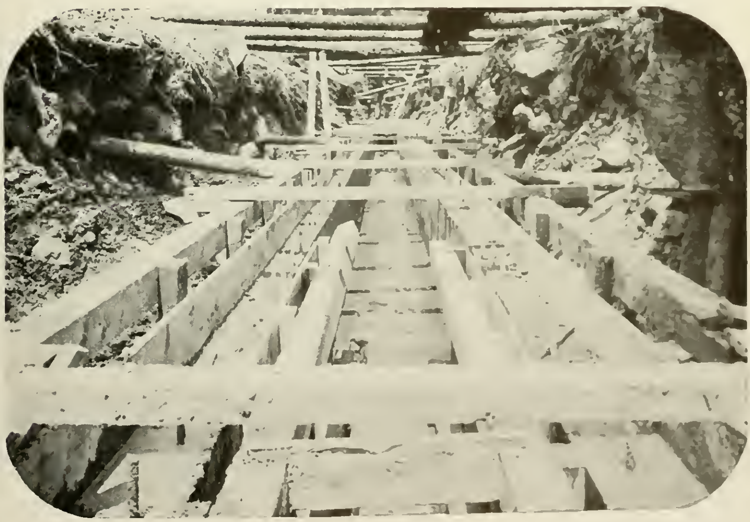


FIG. 2.
DIVERSION CONDUIT. SIDE WALLS LAID

quartzite ledge above referred to, crushed in the sand rolls, was too fine for the fine aggregates. About one half of that portion of it which would pass through a sieve having 8 meshes to an inch would pass through a No. 100 sieve, whereas the specifications required that of the material passing through a sieve with eight meshes to an inch, not more than 12 per cent. should pass through a No. 100 sieve. There was a schist ledge a short distance from the quartzite ledge which consisted of a very fine dense rock weighing 174 lb. per cu. ft., which was better in this respect but not enough so to comply with the specifications.

Careful tests, however, were made to determine both the permeability and strength of concrete and mortar made from mixtures of aggregates from the quartzite and the schist having different proportions of the very fine material, and it was found that with fine aggregates, having a very large proportion of particles which would pass through a No. 100 sieve, the concrete was as strong and as impervious as the concrete made with fine aggregates which only had 12 per cent. that would pass through a No. 100 sieve, and that the 1:3:6 mixture was as impervious as the 1:2:4 mixture. The contractor was, therefore, permitted, provided he would use three skips of the schist rock to one skip of the quartzite rock in his concrete, to use the fine aggregates when the proportion which would pass through a No. 100 sieve would not exceed 40 per cent. of the total which would pass through a sieve with eight meshes to the inch; and Class *C* concrete, concrete blocks, and cyclopean masonry, with the increased fine material in the fine aggregates, was used, as provided in a clause in the contract reserving to the city the right to substitute one class of masonry in the dam for another even to the exclusion of some of the classes, throughout the dam almost entirely where in the preliminary quantities Class *B* concrete, concrete blocks, and cyclopean masonry had been estimated.

In the revised pressure diagram, Fig. 5, made since the completion of the dam, the weight of the masonry is taken as 157 lb. per cu. ft., the volume of the inspection wells being included in the volume of the dam, the weight of the quartzite being 169 lb., and the weight of the schist 174 lb. The weight of the concrete was averaged at 151.2 lb.

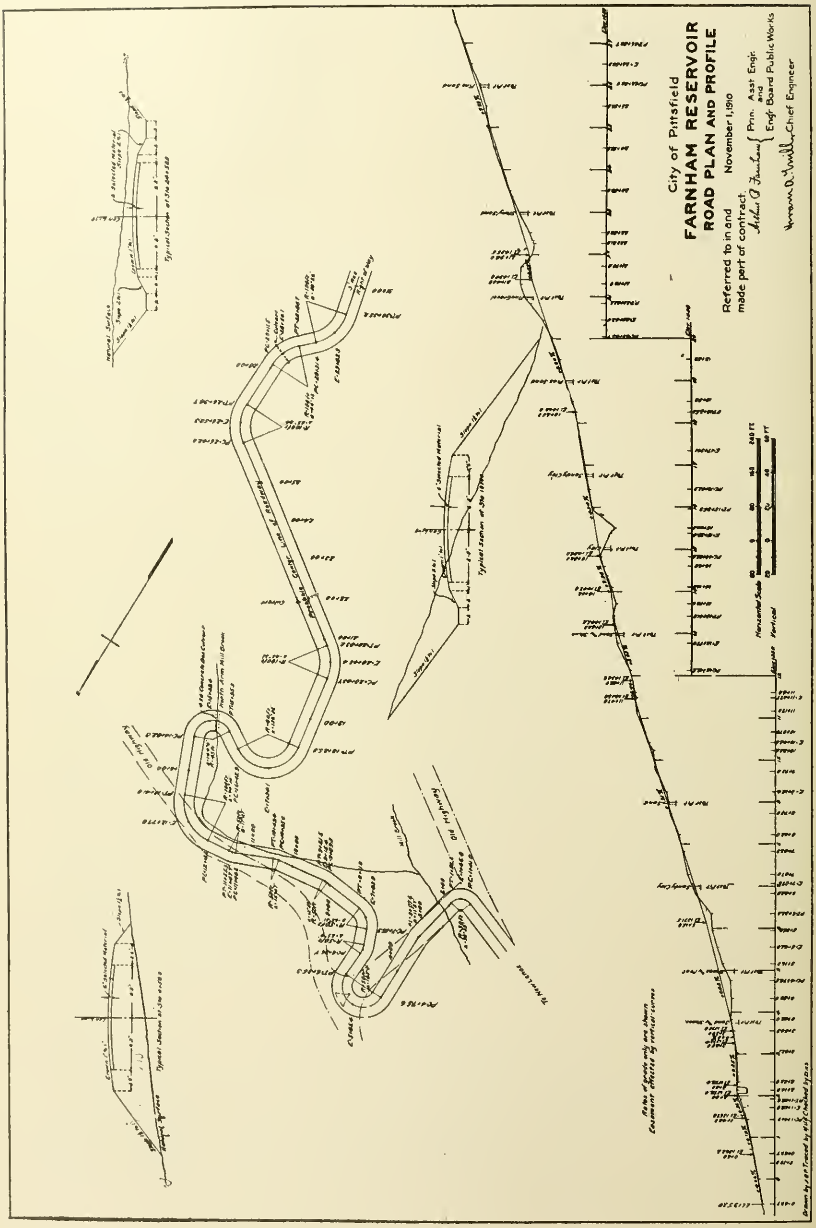

City of Pittsfield
FARNHAM RESERVOIR
ROAD PLAN AND PROFILE
Referred to in and made part of contract.
November 1,1910
Prin. Asst Engr. and Engr. Board Public Works
Chief Engineer

Fig. 6.

Ice pressure was taken at 10 000 lb. per linear foot at the surface of the water. It was assumed that the upward pressure of water under the dam would be equal to the full pressure of the water at the upstream side, and that it would be nothing at three quarters of the distance from the upstream side to the downstream side, either at the bottom of the dam or at any horizontal section of the masonry. The pressure diagram, when the reservoir is empty, shows that the pressure line passes about three inches outside of the middle third, but if the deduction for the inspection wells had been taken out of the vertical longitudinal section in which they are, instead of being distributed through the total volume of the dam, and if the lesser weight of the masonry near the upstream face of the dam (being all concrete) had been taken into account, this pressure line would not have passed outside the middle third. The diagram shows that the pressure will keep within the middle third, in accordance with the above assumptions when the reservoir is full to Elevation 1585—the elevation of the spillway. It will also keep within the middle third with the water at Elevation 1590, provided there is no ice pressure, consequently flashboards 5 ft. high can be safely placed across the spillway, provided they are removed before ice forms on the surface of the reservoir to any great thickness; and provided also that there is no depth of water passing over the spillway.

NEW ROAD.

As the public road passed across the site of the dam and through the site of the reservoir, a new location was made around the easterly side of the dam and along the easterly side of the reservoir. As this was mainly on the steep hillside, a large portion of the construction consisted of excavating on one side of the roadway and depositing the material on the other. (Fig. 6.)

In order to keep the grade down to 8 per cent. it was necessary to pass up one side and along the other side of two streams to get sufficient development.

RESERVOIR.

The area of the reservoir, Fig. 7, is about 42 acres. From this area and for a short distance in height above the flow line, the

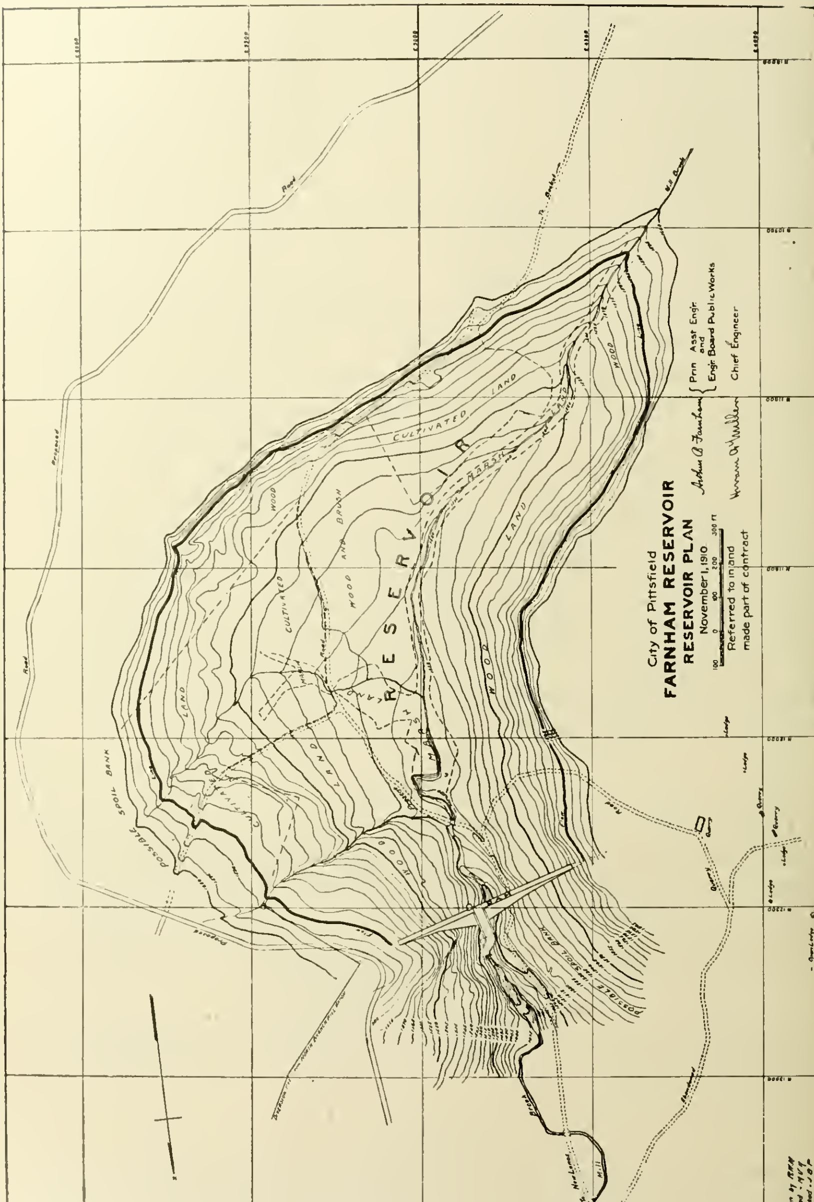

City of Pittsfield
FARNHAM RESERVOIR
RESERVOIR PLAN
November 1, 1910
Referred to in and made part of contract
Prin. Asst Engr. and Engr. Board Public Works
Chief Engineer
RESERVOIR
CULTIVATED LAND
WOOD AND BRUSH
WOOD LAND
MARSH
POSSIBLE SPOIL BANK
Road
Mill Brook

FIG. 7.

soil was entirely removed, except that on an area in the bottom of the reservoir the muck was covered by additional soil and the whole covered with earth taken from the reservoir after the soil had been removed.

The reservoir will contain, below the elevation of the spillway, as measured after the soil had been removed, 446 500 000 gal., and with 5 ft. of flashboards on the dam will contain about 517 500 000 gal.

DIVERSION CONDUITS.

A diversion conduit, Fig. 8, was constructed from a branch in Mill Brook, called Monument Brook, to divert the water from this brook into the proposed reservoir, and a diversion conduit was carried from the Mill Brook watershed along the side of Roaring Brook, and the pond above referred to, intercepting tributaries Nos. 1, 2, 3, 4, and 5, to divert the water from this portion of the Roaring Brook watershed into the reservoir. These conduits were designed to have a capacity of not less than six and one-half million gallons per square mile of watershed tributary to them. Twelve-inch sewer pipe was used for the conduit from Monument Brook. The lower portion of the Roaring Brook conduit is covered and the upper portion is open.

Where it was necessary to have the covered conduit larger than a 24-in. pipe, the conduit consists of a reinforced concrete box, the thickness of the concrete being five or six inches, depending upon the size of the box.

Inlets were provided where required at the side of the covered conduit to admit the run-off from the tributary brooks and from the hillsides. At each inlet and at the upper end of the covered conduit, settling basins were constructed. Where the covered conduit turns away from Roaring Brook a waste gate was provided to permit the water flowing in the conduit to discharge into the brook when desirable.

Where the covered conduit was below the lowest ground water surface, pipes were laid with open joints, or in the case of the concrete box, 2-in. pipes were inserted at frequent intervals in the sides of the box, just above the bottom, for the purpose of leading the ground water into the conduit.

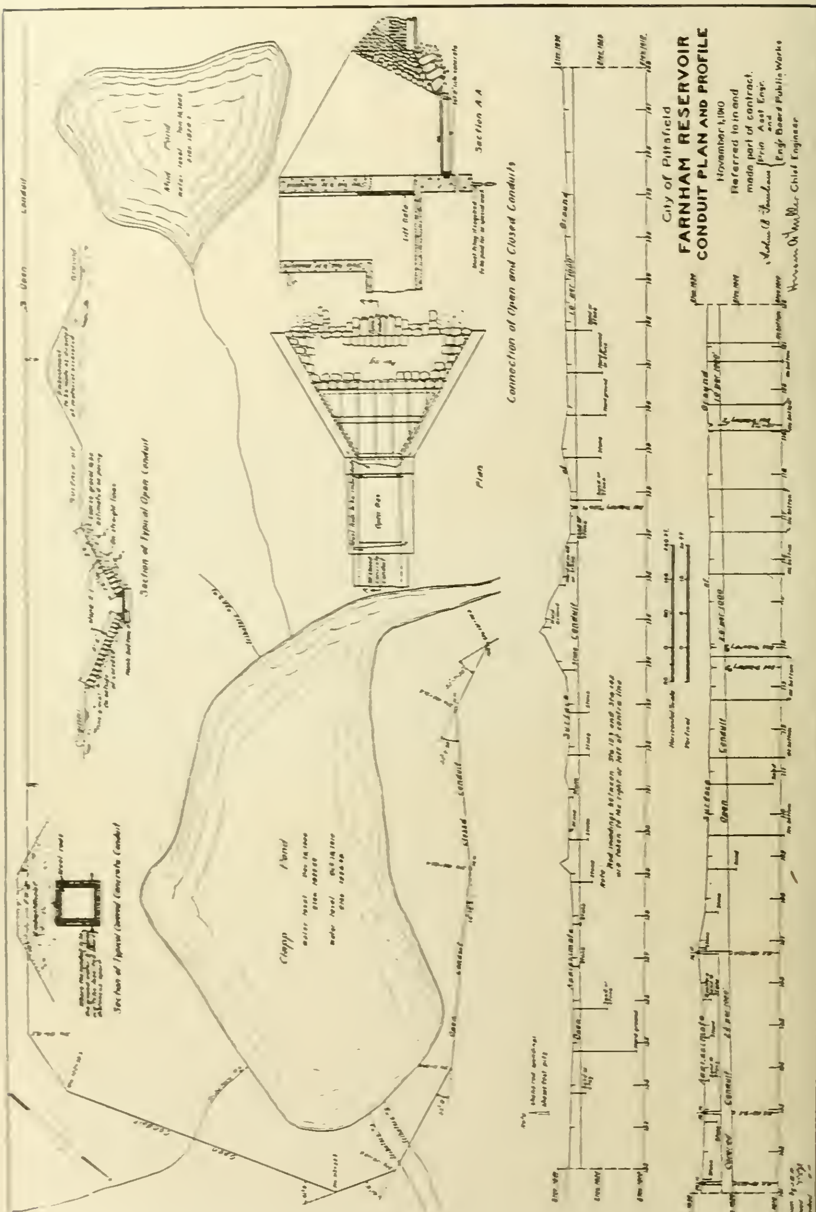

City of Pittsfield
FARNHAM RESERVOIR
CONDUIT PLAN AND PROFILE
Referred to in and
made part of contract.
Chief Engineer
Section of Typical Open Conduit
Connection of Open and Closed Conduits
Section A A
Plan
Clapp Pond

FIG. 8.

FIG. 1.
OUTLET OF DIVERSION CONDUIT.

FIG. 2.
OPEN DIVERSION CONDUIT.

The open conduit consisted of a ditch with two to one slopes on the sides, lined on the bottom with a plank 12 in. wide, on each side of which was the half of a four-by-four scantling sawed diagonally. The sides of the ditch were paved for a distance above the bottom.

Small open-side conduits were constructed at three points on the main open conduit through the swamp to the foot of the hills, to take the water direct from the tributaries and prevent it from flowing over the swamp.

IMPROVING BROOKS.

Between the Mill Brook intake and the Farnham Dam, the brook has a fall of nearly 150 ft. in a distance of about 3 000 ft. Between the outlet of Roaring Brook diversion conduit and the flow line of the Farnham Reservoir, there is a fall of over 200 ft. in about 1 100. These brook channels have been improved and various small dams constructed across them for the purpose of aërating the water.

AVAILABLE SUPPLY OF THE COMPLETED SYSTEM.

The area tributary to the new Farnham Reservoir is estimated to be as follows:

Mill Brook, above the proposed reservoir....	0.38 sq. miles
Diverted from Monument Brook...........	0.20 sq. miles
Diverted from Roaring Brook..............	3.20 sq. miles
Total..................................	3.78 sq. miles

This, added to the original collection area, less that portion of it now tributary to the Farnham reservoir, makes a total collection area of 10.21 sq. miles. The estimated available yield in a series of dry years, with the spillway of the Farnham dam at Elevation 1585, is 5 500 000 gal. per day.

In making the estimate of the available yield of the former and present collection systems in a series of dry years, the records of the Sudbury watershed from June, 1879, to December, 1883, inclusive, were used. Comparisons of the run-off from the Sudbury watershed with weir measurements in Roaring Brook and Mill Brook from September, 1907, to August, 1908, indicate that they are

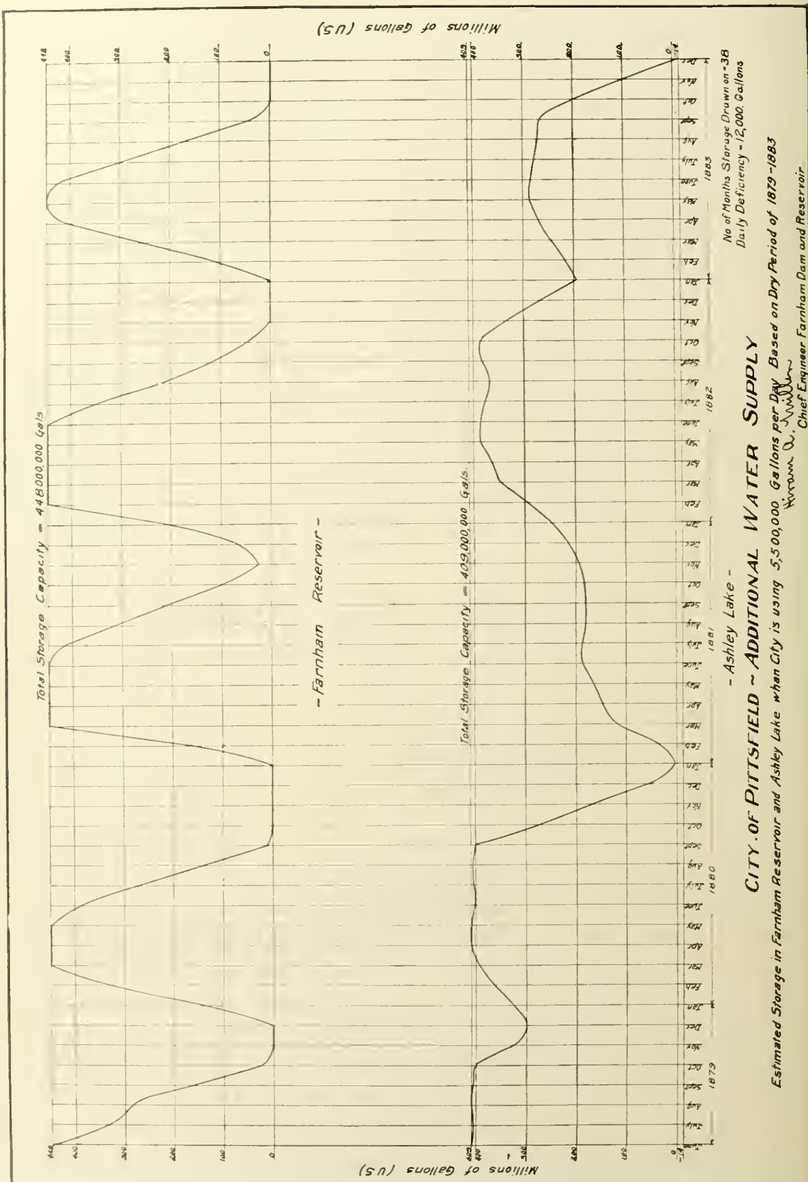

Millions of Gallons (U.S.)
Total Storage Capacity = 448,000,000 Gals.
- Farnham Reservoir -
Total Storage Capacity = 409,000,000 Gals.
- Ashley Lake -
1879
1880
1881
1882
1883
No. of Months Storage Drawn on = 38
Daily Deficiency = 12,000 Gallons
CITY OF PITTSFIELD ~ ADDITIONAL WATER SUPPLY
Estimated Storage in Farnham Reservoir and Ashley Lake when City is using 5,500,000 Gallons per Day Based on Dry Period of 1879-1883
Chief Engineer Farnham Dam and Reservoir
Millions of Gallons (U.S.)

FIG. 9.

very nearly the same, although the yield from the Sudbury reservoir appears to be slightly larger.

ADDITIONAL MAINS.

In order to transmit, throughout the city, the increased quantity of water available by the addition to the water supply, without too great loss of pressure during fires, it was necessary to lay additional mains to and through the city.

The Ashley intake is lower than any of the other intakes, and is nearer to the city than any of them. It is necessary to have pipes of sufficient size for fire protection from this reservoir to the city only, as its storage of 23 000 000 gal. is more than sufficient to last through a fire. It is only necessary to have pipes of sufficient size from the Mill Brook intake, to the connection with the pipes from the Ashley intake, to provide for the maximum daily consumption of the city, less the least yield that can be expected in an extremely dry period from the other watersheds.

In planning the size of the pipes from the Ashley reservoir, it was deemed desirable not to consider the present 12-in. pipe from Ashley Lake to the distribution system, as it was laid with cement joints some forty years ago. A test, however, was made on a portion of two lengths of this pipe, without disturbing the cement joint connecting them. This pipe was subjected to a pressure of nearly 300 lb. per sq. in., and the joint as well as the pipe successfully stood the test. It was decided, therefore, not to abandon this pipe line at the present time, as on the outside it was practically as good as when laid and on the inside was only slightly tuberculated.

In estimating the size of the new pipe necessary to be laid from Ashley Lake to the distribution system it was assumed that the maximum rate of consumption, when the average was 5 500 000 gal. per day, would be 10 000 000 gal. per day; as, for instance, on a Monday morning; that it would be necessary to provide for the use of 4 000 gal. per minute for fire protection, or at the rate of 5 800 000 gal. per day, a total of 15 800 000 gal.; that the pressure at City Hall with this flow should not fall below 40 or 45 lb.; and that the distribution mains should be large enough to maintain good pressure throughout the city.

On this basis it was decided that it would be ultimately necessary to lay a 24-in. pipe from the Ashley intake to the distribution system, and a new 18-in. main from the Mill Brook intake to a connection with the new 24-in. pipe from Ashley intake. It was also decided that the present distribution system should be reinforced with a 20-in. main extending around the westerly side of the city; a 20-in. main extending around the easterly side of the city,

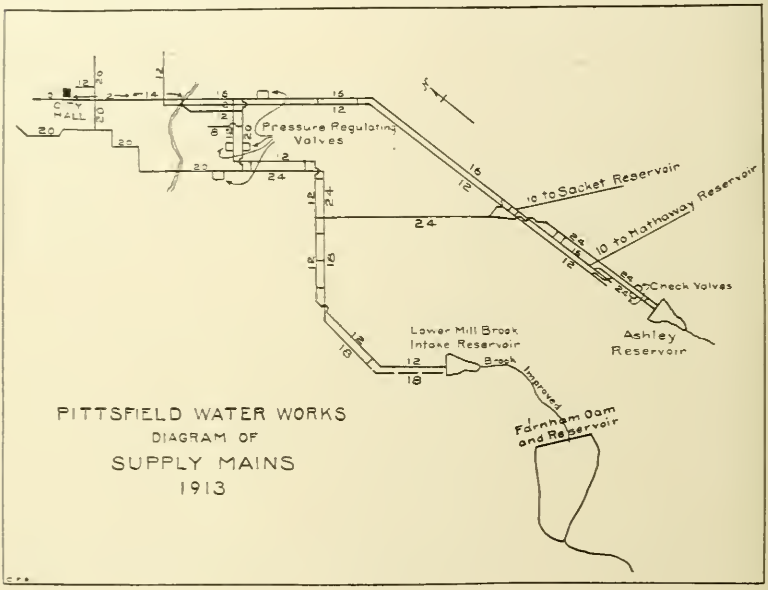


Fig. 10.

and a 20-in. main running north and south through the center of the city.

It was not deemed necessary, however, to do all the work at a time when the consumption of the city was less than 4 000 000 gal. per day. It was, therefore, decided to lay at the present time the main from Ashley intake to the distribution system, an 18-in. main for the greater portion of the distance from the 24-in. main from Ashley intake to the Mill Brook intake; a 20-in. distribution main through the center of the city; a 20-in. distribution main to the westerly side of the city, and leave the construction of the

remaining mains until such time as they should appear to be needed.

As the additional 18-in. pipe from the Mill Brook intake would cause pressures in the city so much higher than had been customary, and as the 12-in. pipe from Ashley intake to the city was so old, it was decided to introduce pressure reducing valves so that the extreme pressure at City Hall and on the 12-in. pipe would not exceed 75 to 80 lb.

If all the valves between the Mill Brook intake and the Ashley intake were left open, the Ashley intake reservoir might overflow; consequently check valves were placed on by-passes and positive gates opposite the check valve on the two mains near Ashley intake so that the flow into Ashley Lake could be regulated by the positive gates, and the check valves, opening toward the city, would open if the pressure dropped in case of fire.

The additional water supply for the city of Pittsfield was in charge of the committee on water supply of the city, consisting of Mr. W. H. Swift, chairman; Mr. James W. Hull, Mr. Arthur H. Rice, Mr. Edward A. Jones, and Mr. Daniel England. Mr. Hull, however, died before the actual work was well under way. Mr. A. B. Farnham, engineer of the board of public works, was principal assistant engineer, and Mr. John L. Howard was resident engineer of the Farnham Dam and Reservoir, and the writer was chief engineer on the Farnham Dam and Reservoir, and consulting engineer on the additional pipe lines.

TORRESDALE FILTER PLANT: METHODS AND RESULTS, 1907–1913.

BY FRANCIS D. WEST, CHEMIST IN CHARGE, TORRESDALE LABORATORY, AND JOSEPH S. V. SIDDONS, SUPERINTENDENT, TORRESDALE FILTERS.

[*Read September 10, 1913.*]

CONDITION OF DELAWARE RIVER AT TORRESDALE INTAKE.

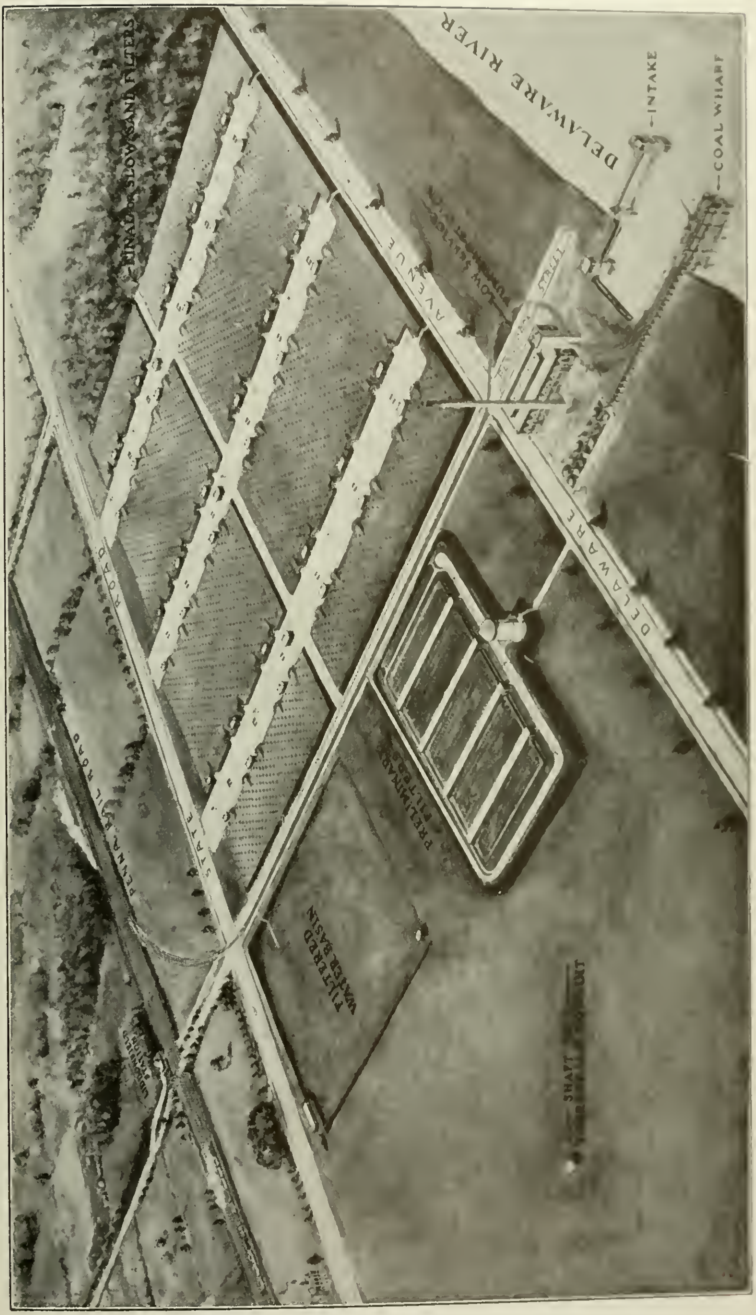
The Delaware River rises in the southeastern part of the state of New York, about 190 miles above Philadelphia. The upper part of its watershed is mountainous and sparsely settled. The area of the watershed is about 8 600 sq. miles. The river is tidal to Trenton, about 18 miles above the Torresdale intake.

The principal affluent of the Delaware above Philadelphia is the Lehigh River, which flows through anthracite regions and reaches the Delaware at Easton, about 75 miles above the city. The principal cities and towns above Philadelphia are Easton, Bethlehem, and Allentown, on the Lehigh; Trenton on the Delaware; and the smaller places within a few miles of the Torresdale plant are Bristol, Burlington, and Riverside.

The Torresdale intake is about 12 miles above Chestnut Street Wharf. It is about 0.25 mile from the Pennypack Creek, which receives the sewage from Holmesburg, and the County Prison and House of Correction. The Pennypack Disposal Plant was built to take care of this sewage. The intake is about 3 miles above Frankford Creek, which is an open sewer and which drains a very thickly populated district. About eight sewers empty into the Delaware between Torresdale intake and Frankford Creek.

By far the worst pollution of the Delaware River comes from the city of Philadelphia, for every flood tide brings heavily polluted water up past the intake. This is especially the case when a heavy wind from the New Jersey shore prevents much mingling of the sewage with the purer water of the channel. To give some idea of what the conditions were before the Torresdale plant was started it is only necessary to state that the intake at Lardner's Point, which was then used, is only a half mile from

WEST ON
TORRESDALE FILTER PLANT.



Frankford Creek, with several large sewers discharging nearby, so dilute sewage was pumped on both tides. Bacillus coli communis is present in over 99 per cent. of the 1 c.c. tests and in about 90 per cent. of the tests of 0.1 c.c.

The range in bacteria in the Delaware River, together with that of the Filtered Water Basin for 1912, is given on Table 1. The range for turbidity for the same year is given on Table 2. Table 3 shows the turbidity for 1907 to 1912 inclusive; maximum, minimum, and average. Table 4 gives the corresponding bacteria. The results of chemical tests are given in Table 5.

TURBIDITY.

The normal turbidity of the Delaware River varies between 10 and 30, with an average of about 15 (between April and December). Occasionally, if winter sets in with heavy rains, the turbidity may reach 100 to 200, and the Torresdale plant will be overtaxed about the time of freezing temperature; ordinarily this is not the case and the river has a turbidity of 30 until the spring freshets, late in February. 1911 was an open winter and the turbidity was low all of the year. In 1912 the ground was frozen and covered with snow until February 22, when heavy rains brought down practically all of the winter's débris; the maximum turbidity, 1 050, was reached March 17. During the five years that the Torresdale plant has been in operation, the turbidity of the river has been 100 or over on 62 occasions, and between 50 and 100, 32 times, an average of 12 and 6 times a year respectively. In 1909 for nineteen days the turbidity was 100 or over. In 1911 a turbidity of 100 was not reached.

Compared with other rivers in the vicinity, the Delaware may be considered as having a remarkably low amount of dirt in suspension; although when we figure out how many pounds of dirt the Torresdale filters remove in a year, the figures are remarkable.

Taking the figure 36 parts per million as the average amount of dirt removed by the filters during 1912, for every million gallons of water there are 300 lb. of mud; filtering at a rate of 200 million gal. a day, about 60 000 lb. of mud per day, or 22 000 000 lb. per year, are removed. On March 17, the turbidity was 1 050, of which 1 000 parts were removed, or 1 660 000 lb. of mud in one

TABLE 1.

RANGE IN BACTERIA. 1912.

Bacteria. Per C. C.	Delaware River. Days.	Effluent of Roughing Filters. Days.	Bacteria. Per C. C.	Filtered Water Basin. Days.
0–100	0	..	0–5	86
101–200	0	..	6–10	101
201–300	0	1	11–25	107
301–400	0	3	26–50	34
401–500	0	6	51–100	15
501–750	1	19	101–200	12
751–1 000	6	55	201–500	4
1 001–1 500	16	44	501–1 000	5
1 501–2 000	36	42	1 001–2 100	2
2 001–2 500	27	31	Over 2 100	0
2 501–25 000	92	93	....	..
5 001–10 000	86	36	....	..
10 001–25 000	67	28	....	..
25 001–50 000	22	6	....	..
50 001–100 000	10	2	....	..
Over 100 000	3	0	....	..

TABLE 2.

RANGE IN TURBIDITY. 1912.

TURBIDITY. Parts per million.	DELAWARE RIVER. Days.	EFFLUENT OF ROUGHING FILTERS. Days.	TURBIDITY. Parts per million.	FILTERED WATER BASIN. Days.
0–10	154	297	0–1	339
11–25	146	41	2–10	18
26–50	38	8	11–25	7
51–100	9	6	25–51	2
101–250	9	6	Over 51	0
251–500	3	6	......	..
501–750	4	2	......	..
751–1 050	3	0	......	..
Over 1 050	0	...	......	..

TABLE 3.

Turbidity 1907–1912, Inclusive.
Parts per million.

Year.	Delaware River.			Effluent of Roughing Filters.			Filtered Water Basin.		
	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.
1907*	190	5	32	. . .	. .	. .	10	0.5	2.8
1908	720	10	39	. . .	. .	. .	18	0	2.1
1909	350	7	37	260	1	12	24	0	.81
1910	60	6	25	130	0.5	8†	8	0	.22
1911	97	5	16	50	0.5	5†	3	0	.07
1912	1 050	2	37	610	0.5	18†	51	0	1.11

* Last six months.

TABLE 4.

Bacteria per Cubic Centimeter (Gelatine 48 hrs. 19° Cent.).

Year.	Delaware River.			Effluent of Roughing Filters.			Filtered Water Basin.		
	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.
1907*	270 000	600	17 000	. . . . .	. . .	. . . .	5 600	12	499
1908	60 000	550	6 600	. . . . .	. . .	. . . .	2 800	22	196
1909	120 000	400	9 100	31 000	100	3 400	2 000	7	103
1910	50 000	490	7 000	15 000	120	2 200	400	2	44
1911	61 000	700	7 600	30 000	250	2 600	480	2	25
1912	120 000	720	11 100	61 000	300	4 600	2 100	1	44

* Last six months.
Preliminary or roughing filters in service, January, 1909.

PLATE XXVIII.
N. E. W. W. ASSOCIATION.
VOL. XXVII.
WEST ON
TORRESDALE FILTER PLANT.

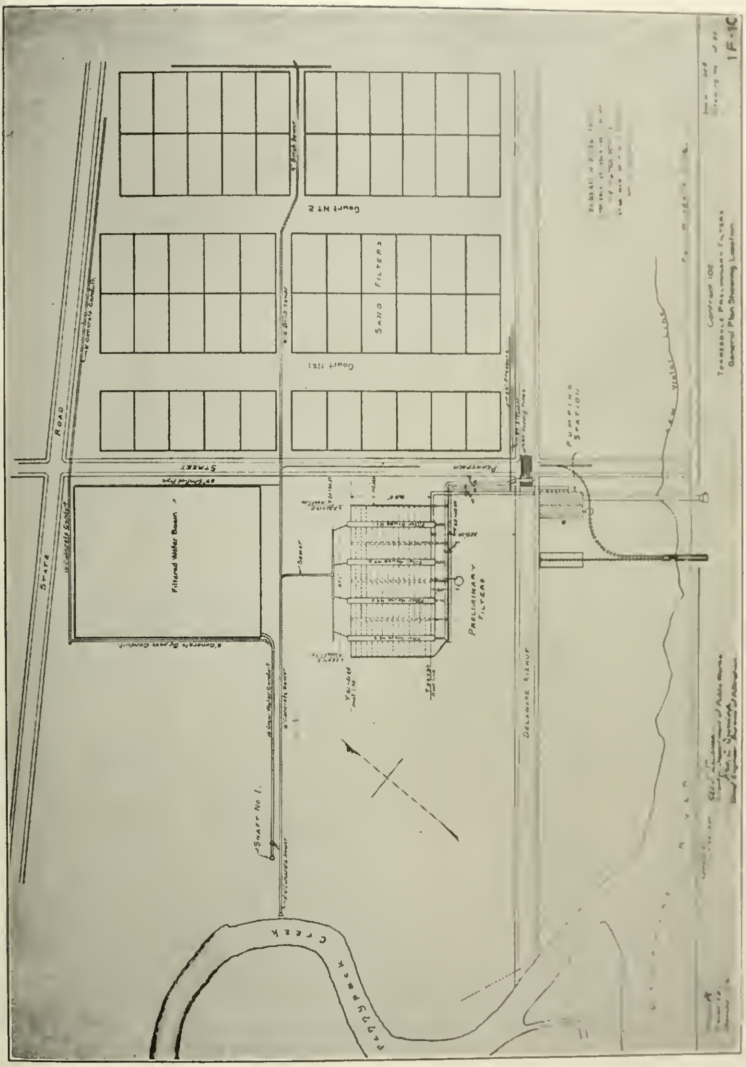


TABLE 5.

CHEMICAL TESTS FOR 1910, 1911, 1912.

Parts per million.

	1910.			1911.			1912.		
	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.
DELAWARE RIVER.									
Total solids	216	117	52	158	107	68	1 136*	103	72
Suspended matter	152	31	4	72	18.5	2	948*	25	1
Fixed susp.	....	.....	....	49	11.1	0	838*	18.5	0
Volatile susp.	....	....	....	23	7.5	2	110*	6.5	1
Turbidity	260	25	6	95	16	5	1 050	37	2
Total ammonia	1.24	.64	.44	.98	.54	.35	.68	.46	.22
Nitrites	.030	.009	.001	.028	.007	.001	.044	.013	.002
Nitrates	.76	.31	.08	.40	.18	.07	.56	.16	.06
Oxygen consumed	7.15	3.55	2.70	5.55	3.50	2.50	14.30*	3.22	2.15
Color	25	15+	10	25	20−	10	25	15+	10
Iron	8.68	2.22	.42	3.98	2.08	.68	30.72*	1.91	.84
Chlorine	10.0	5.3	1.8	7.2	4.5	2.9	8.6	4.4	1.4
Alkalinity	46	27	12	41	24	10	38	26	10
Hardness	62	47	26	69	44	24	59	44	28
Sulphates	16	11	5	19	13	8	17	12	8
FILTERED WATER BASIN.									
Total solids	120	75	36	102	77	44	106	73	52
Turbidity	8	.22	0	3	.07	0	51	1.11	0
Total ammonia	.46	.24	.11	.34	.22	.14	.44	.19	.09
Nitrates	.85	.44	.24	.52	.25	.08	.64	.23	.10
Nitrites	.005	.0005	.000	.002	.000	.000	.008	.0003	.000
Oxygen consumed	3.25	1.85	1.05	3.75	2.00	1.45	2.90	1.80	.80
Iron	.46	.135	.00	.42	.08	.00	1.18	.09	.00

* Not averaged

day. During the two weeks previous about 6 million lb. or 3 000 tons of dirt were filtered out of the water.

BACTERIA.

The bacteria count of the Delaware River fluctuates greatly, depending on the tide, from a few hundred to several thousand. The count is lowest at low tide and increases with the incoming tide. (Tables 1 and 3.)

CHEMICAL TESTS.

Of the chemical tests, those of "Oxygen consumed" and "suspended matter" are the most interesting and valuable. The organic matter in the Delaware is relatively high; about two parts are in solution. The coefficient of fineness, the ratio of the weight of suspended matter to the turbidity, is slightly over unity and the ratio of fixed to volatile suspended matter is about two to one. The Delaware is relatively soft; the hardness ranging from 26 to 69 and the alkalinity from 12 to 46, averaging about 26 parts per million.

MICRO-ORGANISMS.

The operation of the Torresdale Filter Plant is seriously affected by micro-organisms, which usually occur in greatest numbers in spring and summer, when the turbidity is least. During May and June of 1913, when the turbidity of the river was about 12, and that applied to the final beds 3 or thereabouts, the final beds went out of service very rapidly. In addition to the micro-organisms themselves, the water contains considerable amorphous matter, which forms a hard paste on or near the surface of the filters.

The forms most commonly encountered are the diatoms and green algæ. Of the Diatomaceæ, the form most prevalent is the Synedra, followed by Cyclotella, Asterionella, Cymbella, Amphora, and Pleurosigma in the order named, although 90 per cent. are Synedra and Cyclotella. The diatoms are most plentiful in February and again in May, declining during the hot months, but always remaining present.

Of the Chlorophyceæ, Protococcus is the most numerous, then

Conferva, Scenedesmus, and Staurastrum. Protococcus makes up about 80 per cent. The algæ of the chlorophyll type start during May and follow the temperature curve, declining rapidly in November.

Generally speaking, the Delaware River is relatively clear and free from fine silt for the greater part of the year; the turbidity is largely organic, fairly coarse, and removed readily by roughing filters, but containing considerable fine amorphous material which chokes up slow sand filters. It contains, in summer, many micro-organisms which decrease the runs of filters. In late winter the turbidity averages over 100, and is composed largely of fine clay. The water is badly polluted, and B. coli are always present, necessitating disinfection after filtration.

CONDITION OF TORRESDALE FILTER PLANT AT TIME OF STARTING, JULY 4, 1907.

The main plant, or slow sand filters, is composed of 65 $\frac{3}{4}$-acre beds with terra-cotta underdrains and the usual gravel supporting from 26 in. to 36 in. of sand of .25 to .35 mm. effective size and about 2 per cent. coefficient of uniformity. The first 24 beds contained about 36 in. of sand, and the remainder about 26 in.

The Torresdale Filtration Plant was started July 4, 1907. About 25 beds were ready for service; some others contained gravel, and the remainder neither sand nor gravel. The pumps for washing sand had not been installed.

Due to the high typhoid rate in the district supplied with water from the Delaware River and to the fact that promises of starting had been made from time to time, it was considered advisable not to await the completion of the plant but to filter as much as possible, knowing that even unfiltered water from Torresdale intake was better than that at Lardner's Point. The outer intake was not ready, so Gate House No. 2 was used, taking water from a temporary channel about 200 ft. long.

At the start, 40 million gallons were filtered daily. The output was increased gradually as the filters received their quota of sand, 26 in. of sand being placed in the filters instead of 36 in., as had been intended originally.

By November 7, the plant was filtering 60 m.g.d.; by April 13,

TABLE 6.

TORRESDALE FILTERS. YIELD FROM FIRST RUN, 1907–1908.

Month.	No. of Filters Started.	Million Gallons.					Days Run			Turbidity Applied Water.
		Yield.			Average per Acre.	Average Rate per Acre.				
		Max.	Min.	Average.			Max.	Min.	Average.	
1907										
July	29	60	18	38	51	1.7	71	11	30	15
August	1	30	30	30	40	2.6	16	16	16	18
September	9	46	24	36	48	2.3	27	17	21	29
October	9	51	21	37	49	1.6	37	19	30	31
November	5	39	34	35	47	3.4	29	20	14	45
December	2	53	50	31	68	1.9	36	36	36	44
Total	55									
Average	..	..	..	37	49	1.8	..	..	28	30
1908										
April	5	60	47	53	71	1.2	63	57	60	21
May	5	73	57	66	88	1.3	77	64	70	43
Total	10									
Average	..	..	..	59	79	1.2	..	..	65	32

NOTE.—Filters are .75 acre in area.

NOTE.—Rate is in terms of million gallons per acre per day. To get gallons per square foot per hour multiply by .96. To get inches vertical velocity per hour multiply by 1.53.

TABLE 7.

Yield from Torresdale Filters during the Period when the Brooklyn Method of Washing Sand was Employed.

Month.	No. of Filters Cleaned.	Million Gallons.					Days Run.			Turbidity Applied Water.
		Yield.			Average per Acre.	Average Rate per Acre.				
		Max.	Min.	Average.			Max.	Min.	Average.	
1907										
July	14	44	16	26	35	2.7	21	8	13	15
August	48	67	14	25	33	3.0	49	6	11	18
September	65	30	11	18	24	2.4	30	6	10	29
October	75	36	7	20	27	2.0	26	7	14	31
November	96	45	7	16	21	1.5	27	6	14	45
December	95	33	8	17	23	1.5	25	6	15	44
1908										
January	104	44	9	20	27	1.7	26	7	16	51
February	92	61	4	16	21	1.5	42	6	14	100
March	20	45	5	19	25	1.4	31	8	18	48
Total	609									
Average		..	..	19	25	1.8	..	..	14	42

The first runs during 1907, with an average turbidity of 30, yielded an average of 49 million gal. per acre per run at a rate of 1.8 million gal. per acre day.

The ten filters started in 1908, with the same turbidity, yielded an average of 59 million gal. per run, or 79 million per run per acre, operated at a somewhat lower rate — 1.2 million gal per acre day.

The Brooklyn method yielded an average per run of but 25 million gal. per acre, averaging but fourteen days of service, with actual yields of as low as 4 million gal. The turbidity at this time averaged 42.

TABLE 8.

Yield during Period When Method of Scraping and Piling was Used for Washing Sand.

Month.	No. of Filters.	Million Gallons.					Days Run.		
		Yield.			Average per Acre.	Average Rate per Acre.	Max.	Min.	Average.
		Max.	Min.	Average.					
1908									
March	32	56	25	38	51	1.7	38	22	30
April	39	54	21	33	44	2.0	39	14	22
May	45	69	20	35	47	2.0	42	12	23
June	47	66	22	35	47	2.6	32	12	18
July	57	59	27	35	47	2.7	28	13	17
August	71	48	23	33	44	2.4	27	15	18
September	78	51	17	31	41	2.6	26	11	16
October	66	54	19	34	45	2.7	31	10	17
November	61	52	24	36	48	2.8	26	11	17
December	34	54	24	41	55	2.8	30	14	20
Total	530								
Average	..	..	..	35	47	2.4	..	..	19
1909									
January	17	142	25	68	91	2.8	57	12	32
July	2	64	44	54	72	4.8	26	15	15

October	1	..	..	68	91	5.1	..	..	18
November	22	81	19	41	55	4.2	20	6	13
December	35	48	12	29	39	4.3	16	4	9
Total	77								
Average	..	..	..	43	57	3.6	..	..	16
1911									
June	3	72	38	56	75	5.4	19	10	14
1912									
March	42	70	3	35	47	4.7	17	2	10

During 1908 the scraping and piling method yielded almost the same amount as the ejection method, an average of 35 million, compared with 39 million gal. per run.

During 1909 it was used at a different season of the year, and it was not used at all in 1910.

During March, 1912, it was used successfully to get a bed back into service quickly, raking being of no value, due to the deep penetration, and it was necessary to keep the filters working.

Although by April, 1912, the average turbidity had dropped to 12, and by May to 2, the filters were still in such a condition that in May 65 filters were spaded, getting a maximum run of 229 million and a minimum of 11 million, with an average of 51 at a 4.5 million rate.

From March 1 to May 15, it was necessary to work twenty-two hours a day, due to the deep penetration caused by the high turbidity of February and March.

1908, the quantity was 86 m.g.d., and by May 12, 110 m.g.d., the maximum without pre-filters. The maximum rate was 3 million gallons per acre daily. Table 6 shows the yield from the filters from the first run, 1907–1908.

BROOKLYN METHOD.

As has been stated, the wash pumps were not ready and so it was necessary to resort to other means of washing sand. The Brooklyn method was used.

This method originated in the Department of Water, Gas, and Electricity of the City of New York, and had been used successfully at Jerome Park and Hempsted. It obviates the removal of sand from the filter.

"The water is drained to a depth of a few inches above the sand surface and the outlets, which permit the water remaining above the surface of the sand to flow off, are opened. The wash water is applied at one end of the bed and flows over the sand with a velocity of about 0.5 ft. per sec. The direction is guided by boards set on edge, thus forming channels of the width of a bay, or 15 ft. As the water flows over the sand the layer is raked by men standing on the surface until the water runs practically clear, when the water is applied through the usual inlets and filtration resumed."

This method was used until March, 1908. It was not a success, due to the peculiar quality of the sediment; the combination of amorphous organic material, clay, and micro-organisms formed a hard pasty-like layer extending down for a depth of about 4 in. and of such a consistency that it was possible to hold a large cake of it on the hand without its breaking apart.

As would be expected with green filters, the efficiency during 1907 was not high. The runs were short, and after the output had reached 100 million gal. it was necessary to resort to extreme measures to get water through the filters.

Quantity became all-important; quality was a decidedly second consideration. To assist in getting water through the filters the method of spading was used. This consisted of going over the surface of the filter with a garden spade, thrusting it down to a depth of about 8 in., and working it back and forth to break up the pasty layer.

EJECTOR IN COURT, RESTORING SAND.

Needless to state, this caused a further drop in efficiency with but little assistance in length of runs. Runs became as short as 4 million gal.

Table 7 shows the yield during the period when the Brooklyn method was employed for washing sand.

The Brooklyn method was finally abandoned, and the upper end of the dirty sand was scraped into piles. The filter was then put back into service in the usual manner. This method reduces the effective size by about 15 per cent. It originated at Torresdale and was born of necessity. It is a convenient way to get a filter back into service quickly. The effluent compares favorably with that from any other method.

Table 8 shows the yield of the filters at this time.

As soon as the pumps had been installed, the regulation ejection method for washing sand was used, the sand being scraped into piles, placed in the ejectors, and carried out with the dirt into the court by a force of water under a pressure of 85 lb. per sq. in.

It was necessary to pare off about 8 in. to get down to clean sand.

Table 9 shows the yield of the filters while this method was in use.

PRELIMINARY FILTERS.

These filters are of the mechanical type without coagulant. They are arranged in batteries of 15 beds, with two batteries facing each filter house, of which there are four; making 120 beds. Each bed measures 20 ft. 3 in. by 60 ft. and is controlled by an individual operating table. The influent is through a 16 in. hydraulic valve in the rear. The filtering material consists of 15 in. of gravel, 2 in. to 3 in.; 4 in. of gravel, $\frac{5}{8}$ in. to $1\frac{1}{2}$ in.; 3 in. of gravel, $\frac{1}{4}$ in. to $1\frac{1}{2}$ in.; and 8 in., $\frac{1}{8}$ in. to $\frac{1}{4}$ in., a total of 30 in. and 12 in. of sand, with effective size .8–1.0 mm.

The depth of water over the bed is 4 ft. They are washed by reverse flow of water with air.

The period of washing is, air, three minutes; water, one minute; air, two minutes, and water, $1\frac{1}{2}$ minutes, when the filters are filled and put into service. Washing without air was tried, but it was found that the wash water passed through channels and a thorough wash was not obtained.

TABLE 9.

YIELD FROM FILTERS DURING PERIOD WHEN EJECTION METHOD WAS USED FOR CLEANING SAND.

Month.	No. of Filters Removed.	Million Gallons.					Days Run.			Turbidity Applied Water.	Average Cubic Yards Sand Removed.
		Yield.			Average per Acre.	Average Rate per Acre.					
		Max.	Min.	Average.			Max.	Min.	Average.		
1908											
March	9	61	43	50	67	2.1	40	25	32	44	261
April	28	52	25	39	52	2.3	39	18	24	21	269
May	29	80	26	42	56	2.5	45	14	22	43	261
June	49	80	23	38	51	2.7	34	14	19	30	187
July	37	69	23	38	51	2.5	32	12	20	26	152
August	25	56	21	38	51	2.7	31	13	19	28	211
September	28	42	19	33	44	2.8	23	10	16	29	223
October	30	49	24	37	49	2.7	24	11	18	30	275
November	29	64	23	42	56	2.8	29	11	20	35	296
December	18	75	29	45	60	2.6	34	12	23	39	374
Total	282										
Average	..	..	..	39	52	2.6	..	..	20	32	239
1909											
January	13	261	80	168	224	3.6	79	35	63	29	417
February	21	373	168	235	313	4.3	105	57	72	24	344
March	12	379	121	260	347	4.3	104	52	80	8.3	277
December	16	199	37	108	144	5.1	50	11	28	56	433

Total	62										
Average	..	..	..	193	257	4.3	..	..	60	29	375
1910											
January	54	191	43	97	129	4.4	53	18	29	17	355
February	14	249	60	174	232	4.7	65	18	49	17	305
March	3	292	144	232	309	4.0	91	50	77	16	422
Total	71										
Average	..	..	..	118	157	4.4	..	..	35	17	348
1911											
April	2	125	97	111	148	3.5	45	40	42	7	342
June	16	195	50	78	104	4.0	63	19	26	5	112
July	2	83	72	77	103	4.5	24	21	23	1	145
Total	20										x
Average	..	..	..	81	108	4.1	..	..	27	4	133
1912											
March	82	187	10	64	85	5.0	55	4	17	95	324

In 1908, without pre-filters, with a turbidity of 32, the average yield was 39 million gal.; in 1909, with pre-filtered water and deep cleanings, the average yield was 193 million, with about the same turbidity.

In 1910, under somewhat better conditions as regards turbidity, the average yield was 118 million gal.

In the summer of 1911, with a turbidity of but 4, the average yield was only 81 million gal., showing the effect of micro-organisms.

In 1912, at the time of the record turbidity, we had one run of but 4 million gal. and another one of 187 million.

The pre-filters have removed over 60 per cent. of the dirt; have made it possible to double the output of the plant, giving 210 million instead of 110 million gal. per day; have enabled the final beds to be operated at a maximum of 6 instead of 3 million gal. per acre per day; have more than doubled the lengths of runs of the final beds, as well as the quantity filtered per run, as will be seen by tables; and have made a marked reduction in the cost per million gallons filtered.

REMOVAL OF SUSPENDED MATTER.

The principal usefulness of a roughing filter is to remove the turbidity or suspended material. The average by months for the past four years is shown in Table 10, and Fig. 1.

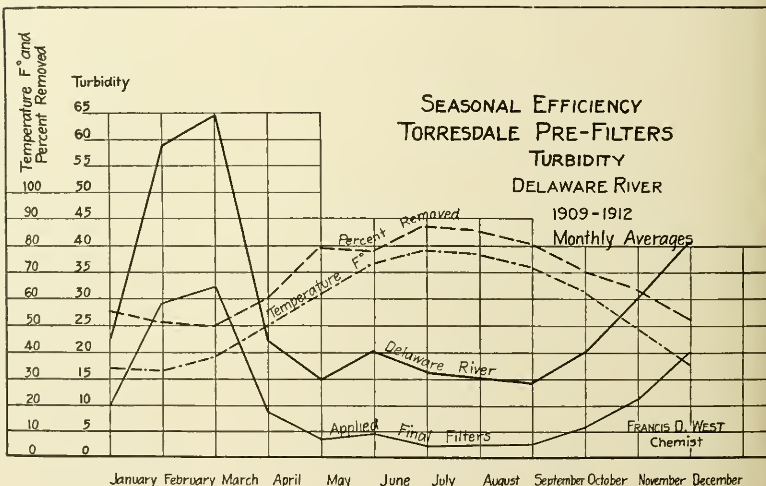


FIG. 1.

It will be seen from Fig. 1 that the amount of turbidity is highest in February and March, with a secondary rise in December; also that the amount between April and October averages about 15 parts per million.

The efficiency seems to vary as the temperature, although this may be due to the fact that the turbidity in summer is low; how-

TABLE 10.

TURBIDITY. TABLE SHOWING SEASONABLE EFFICIENCY OF PRE-FILTERS AT TORRESDALE, 1909–1912, INCLUSIVE.

Month.	1908.	1909.			1910.			1911.			1912.			Average, 1909–1912, inclusive.		
	River.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.	River.	Applied.	Per Cent. Removed.
January	54	40	29*	..	36	17	53	24	9.8	59	8.0	3.2	60	23	10	56
February	100	60	24	60	50	17	66	24	9.5	60	109	64	41	61	29	52
March	48	25	8.3	67	30	16	48	15	8.5	43	179	95	41	62	32	49
April	21	20	6.1	59	26	9.3	64	16	7.1	56	25	12	52	22	8.7	60
May	36	24	5.6	77	17	3.5	79	9.0	2.0	78	10	2.4	76	15	3.4	79
June	30	23	2.6	89	24	6.7	72	20	5.4	73	12	2.8	77	20	4.4	78
July	26	27	4.5	83	15	2.0	87	11	1.2	89	10	.8	92	16	2.1	87
August	28	25	4.7	81	14	1.9	86	12	1.5	88	9.5	1.2	87	15	2.3	85
September	29	21	4.1	80	14	2.0	86	13	3.6	72	9.5	1.3	86	14	2.8	80
October	30	31	10	68	18	2.3	87	10	3.4	64	22	8.0	64	20	5.9	70
November	35	33	14	58	37	13	65	18	6.6	63	30	12	60	30	11	63
December	40	108	56	48	28	10	64	14	5.5	61	18	8.0	56	41	20	52
Average	39	37	12*	68	25	8*	67	16	5*	67	38	18*	52	29	11	62

* Omitted from calculations. In operation only a few days.

TABLE 11.

TABLE OF MONTHLY BACTERIAL EFFICIENCY OF PRE-FILTERS AND FILTER NO. 1 FOR YEAR 1911. (BACTERIA PER C. C.)

Month.	River.	Applied Final Filters.		Effluent Final Filter No. 1.	
			Per Cent. Removed.		Per Cent. Removed.
January	4 450	2 430	45.2	28	98.8
February	6 200	2 320	62.6	64	97.2
March	4 320	1 610	62.7	16	99.0
April	3 390	1 490	54.6	15	99.0
May	8 050	2 580	68.0	13	99.5
June	8 370	2 920	65.1	13	99.6
July	8 500	2 460	71.2	8	99.7
August	10 800	2 700	73.2	8	99.7
September	8 950	3 380	62.2	8	99.8
October	4 500	1 980	56.0	6	99.7
November	12 900	4 880	62.1	48	99.0
December	8 450	3 110	63.2	38	98.8
Average	7 410	2 550	65.6	22	99.1

ever, the turbidity does rise occasionally in May, when the efficiency of the pre-filters is high; both the pre- and final filters appear to experience no difficulty in handling a comparatively high turbidity if it comes after the last of April. It will be seen that the efficiency is but 50 per cent. in March and nearly ninety in July.

REMOVAL OF BACTERIA.

This is of secondary importance, but the pre-filters have averaged for the four years as follows: 1909, 62.6 per cent.; 1910, 68.1 per cent.; 1911, 65.5 per cent.; 1912, 60.4 per cent. The efficiency varies from sample to sample without any apparent consistency; there is an apparent removal of 90 per cent. one day, and 60 per cent. the next.

Table 11 gives the bacterial efficiency for 1911 and shows the number of bacteria in the river, in the effluent of the pre-filters, and in that of a typical slow sand filter for a normal year, 1911.

As a rule, when the turbidity efficiency drops, with high turbidity, the bacterial efficiency drops as well, though not so markedly.

Generally speaking, the pre-filters remove about 65 per cent. of the bacteria.

The efficiency in removing micro-organisms is about 60 per cent. but it is thought that they grow on the final filters in spite of the fact that the covers are kept closed.

The following table shows the lengths of runs of pre-filters:

Year.	Total Washing.	No. per Filter.	Per Cent. Wash Water.	Average Days Run per Filter.	Turbidity.
1909	12 648	105	.5	3.4	37
1910	40 119	334	1.0	1.1	25
1911	22 763	190	.6	1.9	16*
1912	19 130	159	.7	2.3	37

* Washed at 3-ft. loss of head.

After continuous use for four years the amount of sand has been reduced by about 2 in., due to loss in washing and to the fact that some has fallen through to the gravel; the finest gravel and some

TABLE 12.

YIELD FROM FILTERS DURING PERIOD WHEN NICHOLS METHOD OF CLEANING SAND WAS USED.

Month.	No. of Filters Cleaned.	Million Gallons.					Days Run.			Turbidity.	Cubic Yards Sand Cleaned.
		Yield.			Average per Acre.	Average Rate per Acre.					
		Max.	Min.	Average.			Max.	Min.	Average.		
1909											
January.....	6	281	104	208	277	4.1	97	50	68	29	418
February....	6	519	272	340	453	5.0	122	55	90	24	374
March......	7	366	256	319	425	4.9	99	69	86	8.3	267
April.......	8	309	212	261	348	5.3	81	54	66	6.1	196
May.......	14	195	71	127	169	3.9	52	32	43	5.6	215
June.......	19	153	60	102	136	4.9	39	19	28	2.6	207
July........	31	171	53	95	127	5.1	43	16	25	4.5	216
August.....	25	110	62	87	116	4.8	29	19	24	4.7	147
September...	22	137	59	95	127	5.1	34	20	25	4.1	120
October.....	23	142	73	101	135	5.2	35	23	26	10.0	170
November...	32	122	63	96	128	5.1	32	17	25	13.5	236
December...	36	235	51	120	160	5.0	62	18	32	56.0	359
Total.....	229										
Average...	...	...	...	123	164	4.5	...	...	34	...	229

1910											
January.....	0	...	...	...	...	...	...	..	..	17	...
February....	20	569	215	340	453	5.0	148	68	91	17	486
March......	17	376	289	329	439	4.4	115	91	99	16	740
April.......	13	293	133	225	300	4.5	86	47	66	9.3	923
May........	9	222	142	185	247	4.4	72	42	56	3.5	896
June........	11	244	74	144	192	4.5	73	22	42	6.7	726
July........	28	283	92	193	257	4.6	76	25	56	2.0	527
August......	27	241	122	178	237	4.0	64	53	60	1.9	368
September...	9	164	68	114 –	152	3.7	61	27	41	2.0	391
October.....	29	132	75	102	136	4.0	43	29	34	2.3	267
November...	33	226	93	148	197	4.7	64	29	42	12.7	268
December...	36	278	112	210	280	4.9	76	31	59	10.5	388
Total.....	232										
Average...	...	...	...	195	260	4.5	...	..	58	..	470

TABLE 12.—*Continued.*

YIELD FROM FILTERS DURING PERIOD WHEN NICHOLS METHOD OF CLEANING SAND WAS USED.

Month.	No. of Filters Cleaned.	Million Gallons.					Days Run.			Turbidity.	Cubic Yards Sand Cleaned.
		Yield.			Average per Acre.	Average Rate per Acre.					
		Max.	Min.	Average.			Max.	Min.	Average.		
1911											
January.....	23	292	189	251	335	4.9	72	63	69	9.8	475
February....	13	359	203	268	357	4.8	99	58	74	9.5	1 230
March......	18	401	160	293	391	4.8	102	50	82	8.5	796
April.......	19	249	112	177	236	4.5	67	48	53	7.1	583
May........	7	174	57	104	139	3.5	59	27	40	2.0	842
June........	22	156	76	110	147	4.6	48	23	32	5.4	436
July........	35	170	65	114	152	3.8	49	27	40	1.2	265
August.....	17	156	49	116	155	3.7	46	20	42	1.5	444
September...	28	203	82	125	167	4.2	75	27	40	3.6	332
October.....	27	149	58	112	149	3.6	57	27	41	3.4	318
November...	30	346	95	159	212	3.9	97	37	54 –	6.6	320
December...	26	233	83	160	213	4.3	70	32	50	5.5	333
Total.....	265										
Average...	...	...	...	160	213	4.3	...	..	50	...	452

1912											
January	31	235	59	138	184	4.8	58	21	38	3.2	266
February	21	117	30	60	80	3.8	36	11	21	64.0	283
March	11	289	134	182	243	4.7	80	34	49	72.0	1 010
April	30	262	120	149	199	3.5	74	39	56	12.0	1 093
May	22	179	73	119	159	3.8	62	28	42	2.4	1 130
June	23	195	83	139	185	4.1	60	30	45	2.8	418
July	26	206	78	151	201	4.2	63	24	48	.8	285
August	22	202	71	154	205	4.1	73	25	50	1.2	249
September	25	112	70	91	121	3.5	44	30	35	1.3	198
October	33	124	54	88	117	3.5	49	21	33	8.0	284
November	27	146	90	117	156	3.8	48	32	41	11.7	319
December	32	207	93	137	183	3.8	71	31	49	8.0	301
Total	303										
Average	...	...	...	126	168	4.3	...	..	39	...	466

On examining the table of Nichols method, it will be seen that the filters cleaned during February, March, and April have the longest runs, the lengths of the runs decreasing until about June and then averaging about the same for the rest of the year.

It will also be noticed that the runs are longer than those obtained from any other method. The average yields for the four years being, 1909, 123; 1910, 195; 1911, 160; and 1912, 126 million gal.

The longest run in the history of the plant, 148 days, was from a filter cleaned by this method, the quantity being 569 million gal. The second longest run, of 122 days for 519 gal., occurred after a cleaning in February, 1909.

One inch depth corresponds to 100 cu. yd. of sand cleaned, so the figures in cubic yard will give the average depths of cleaning by this and the ejection method.

After the freshet of 1912, it was necessary to clean for a depth of 10 in. during March, April, and May, showing the deep penetration.

We are about to start one filter with the Brooklyn method, to see how this method will work with pre-filtered water; but from the deep penetration shown by the above tables it is thought that we will experience the same difficulty as before, the runs becoming gradually shorter the longer the method is used.

of the next grade are mixed with the sand. In a couple of years at most the material will have to be regraded; except for this, the plant is operating as effectively as it did at the start.

There is no question that if we had about 24 in. of sand instead of 12 in. the efficiency would be greater in winter.

The maximum output of the plant was 240 million gal.; the average has been about 200 million since the starting of the pre-filters.

METHODS OF CLEANING FINAL FILTERS.

Almost coincident with the start of the pre-filters was the introduction of the Nichols machine. This, together with raking as an auxiliary, has practically superseded all others at Torresdale.

NICHOLS METHOD.

Mr. E. M. Nichols, after experimenting for about three months at Torresdale, designed a machine which enables the operator to wash the sand on the filter without ejecting, thereby saving about 25 cents per cu. yd. It has the further advantage that the thickness of the filter is not reduced and the danger of breaking through is greatly lessened; moreover, the filter can have the rate changed with less danger of reducing the efficiency.

The machine consists of an inverted cylinder inside a closed jacket. The dirty sand is fed into ejectors in the usual manner, and the wash water with the sand and dirt instead of going out to the court passes through the machine. The water strikes the side of the cylinder and the sand, being heavy, drops to the bottom and is allowed to pass through a nozzle and spread on the filter It has a turbidity of about 150 to 200, i. e., 100 gm. of sand in 1 000 c. c. of water. It uses but 1 200 gal. per cu. yd. instead of 2 800 used by ejection method.

About 2 per cent. of the fine sand goes out with the water and dirt to the court where it settles, the water and dirt going to the sewer.

The depth cleaned at one time by this machine depends upon the penetration and may vary from a couple of inches to 8 or 10 in.

Sometimes a preliminary cleaning will be given if the filter is needed when the upper inch or so is removed, reserving a deeper cleaning for a later date when the pressure for water has been relieved.

FIG. 1.
CLEANING BY NICHOLS MACHINE.

FIG. 2.
RESTORING SAND BY NICHOLS MACHINE. MACHINE IN FILTER.

Table 12 gives the yield of the filters while the Nichols method has been in use.

RAKING.

This is going over the filter with rakes and breaking up the *schmutzdecke*, enabling the operator to get several million gallons at a very low cost. We rake once and sometimes twice between washings.

In 1912, at the time of the flood, practically every method except the Brooklyn was used to get the water through, and if it had not been for the hypochlorite, the water would have had a very high count and contained pathogens.

Table 13 gives the yield of the filters while the raking method was used.

Table 14 gives a summary of the results from the different methods of cleaning sand.

LOSS OF HEAD IN SPRING.

There is one period of the year when we have what we call a loss of head; this may last for a couple of weeks or only for one or two days.

It usually follows the spring freshets when the water has become normal and the turbidity low. The filters instead of increasing in resistance decrease, and the head drops. There appears to be something that destroys the *schmutzdecke* at this time faster than it forms. On a couple of pans that we had placed in one of the filters previously we found from 200 to 300 snails. These may or may not have had something to do with the loss of head. The bacterial efficiency at this time remained high.

GENERAL EFFICIENCY OF PLANT.

The average bacterial efficiency has been as follows:

1907	97.65 per cent.
1908	97.05 per cent.
1909	99.01 per cent.
1910	99.36 per cent.
1911	99.67 per cent.
1912	99.60 per cent.

We have on many occasions had counts of o per c.c. (on gelatine) in not only the filtered water basin but the effluent of filters.

TABLE 13.

YIELD FROM FILTERS DURING PERIOD WHEN METHOD OF RAKING HAS BEEN EMPLOYED.

Month.	First Rake.			Second Rake.			Third Rake.		
	No. Filters.	Yield.*	Days Run.	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.
1909									
January....	32	67	33	4	48	20	..	..	..
February...	7	128	40	1	55	27	..	..	..
March.....	6	117	41	..	..	..	..	..	..
April......	19	144	45	2	89	29	..	..	..
May.......	12	132	38	2	93	38	1	23	12
June.......	26	67	17	23	48	13	5	41	12
July.......	33	94	24	18	70	19	6	47	14
August....	23	92	24	27	75	20	1	52	13
September..	23	97	25	18	67	19	12	55	17
October....	26	65	18	29	47	14	22	41	14
November..	20	43	13	25	34	12	21	31	10
December..	33	31	10	2	35	13	..	..	..
Total....	260			151			68		
Average..	...	80	20	...	56	17	..	40	13

1910									
January....	13	42	14	...	..	..	..	..	..
February...	29	73	22	1	93	28	..	..	..
March.....	7	84	29	3	65	22	..	..	..
April......	19	122	37	13	43	16	..	..	..
May.......	...	...	..	...	...	..	1	47	23
June.......	34	67	19	17	43	14	2	29	12
July.......	25	122	33	32	57	16	1	36	11
August.....	6	183	49	10	82	20	..	..	..
September..	17	94	25	7	67	18	..	..	..
October....	32	91	25	7	53	16	..	..	..
November..	28	71	21	8	35	12	..	..	.
December..	26	54	17	9	28	10	..	..	..
Total....	236			107			4		
Average..	...	84	26	...	52	17	..	35	14

* To get yield per acre per run, multiply by $\frac{4}{3}$.

TABLE 13.—*Continued.*

Month.	First Rake.			Second Rake.			Third Rake.		
	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.	No. Filters.	Yield.	Days Run.
1911									
January....	14	76	26	..	..	..	..	..	..
February...	17	80	26	1	44	19	..	..	..
March.....	23	93	31	11	35	13	..	..	..
April......	9	172	44	11	44	23	..	..	..
May.......	8	113	33	4	111	28	..	..	..
June.......	39	63	17	15	37	12	..	..	..
July.......	37	111	22	8	58	15	..	..	..
August.....	22	107	26	13	67	16	..	..	..
September..	18	113	28	9	69	16	1	53	19
October....	27	114	23	5	65	18	..	..	..
November..	31	95	24	2	44	13	..	..	..
December..	14	82	22	1	62	22	..	..	..
Total....	259			84			1		
Average..	...	98	26	..	49	14		53	19

1912				First	Raking				
January....	31	130	24	67	89	5.2	30	8	17
February...	21	97	3	59	79	5.3	22	2	15
March.....	..	..	..	..	..	..	..	..	..
April......	2	75	68	71	95	4.7	20	20	20
May.......	11	162	98	133	177	5.2	40	29	24
June.......	46	182	33	96	128	5.1	48	8	25
July.......	11	172	78	96	128	5.3	50	19	24
August.....	22	157	74	110	147	5.1	38	20	29
September..	30	117	62	88	117	5.1	31	17	23
October....	30	104	41	75	100	5.0	34	12	20
November..	26	119	40	77	103	4.7	30	10	22
December..	27	79	27	57	78	4.3	25	12	18
Total....	257								
Average..	..	..	..	83	111	5.0	..	..	22

TABLE 13. — *Concluded.*

Month.	No. Filters Raked.	Million Gallons.					Days Run.		
		Yield.			Average per Acre.	Average Rate per Acre.			
		Max.	Min.	Average.			Max.	Min.	Average.
1912				*Second*	*Raking*				
January....	1	17	17	17	23	3.8	6	6	6
February...	..	..	..	..	..	..	..	..	..
March.....	..	..	..	..	..	..	..	..	..
April......	..	..	..	..	..	..	..	..	..
May.......	..	..	..	..	..	..	..	..	..
June.......	6	72	33	53	71	4.7	20	9	15
July.......	15	58	35	50	67	4.2	17	10	16
August.....	5	76	42	64	85	4.7	21	12	18
September..	9	79	35	56	75	5.0	24	8	15
October....	10	71	32	48	64	4.6	24	19	14
November..	13	49	18	31	41	3.7	15	7	11
December..	7	39	16	27	36	3.6	15	7	10
Total....	66								
Average..	..	..	..	45	60	4.3	..	..	14

TABLE 14.

Summary of Different Methods of Cleaning.

No. of Filters Cleaned.	Million Gallons.					Days Run.		
	Yield.			Average per Acre.	Average Rate per Acre.			
	Max.	Min.	Average.			Max.	Min.	Average.
			Method	*First Runs.*				
65	73	21	40	53	1.6	77	11	34
			Brook	*lyn.*				
609	67	4	19	25	1.8	49	6	14
			Scraping	*and Piling.*				
530	69	17	35	47	2.4	39	10	19 Before pre-f.
122	142	3	40	53	4.0	57	2	14 After pre-f.
			Ejection	*Method.*				
282	80	19	39	52	2.6	45	10	20 Before pre-f.
235	379	10	116	155	4.5	105	4	34 After pre-f.
			Rak	*ings.*				
1 012	182	3	85	113	5.0	50	2	24 1st rake.
408	79	16	50	67	4.3	24	7	16 2d rake.
62		39	52					13 3d rake.
			Nichols	*Method.*				
1 029	569	49	141	188	4.4	148	11	42
			General	*Averages.*				
1 486	80	4	30	40	2.1	77	6	18 Before pre-f
2 958	569	3	96	128	4.4	148	2	29 After pre-f.

Note. — Data for Max., Min., and Rate for Rakings for 1909, 1910, and 1911 not given. Method of spading for 1912 omitted from averages.

The average count for the basin under normal conditions is below 10.

The water is clear with a turbidity of 0 for about forty-eight weeks of the year.

We are putting out enough water to supply London: are operating our slow sand filters at twice the standard rate: we have no sedimentation basin but must take the water in large doses just as we find it, and we have an effluent which compares favorably with that of any plant in existence.

HYPOCHLORITE.

Bleach was first used at Torresdale in the form of hypochlorite of soda produced electrolytically, during September, 1909. Two cells manufactured by the National Laundry Company were used. A current of 35 amperes at 110 volts was used to decompose a brine solution. The temperature of the bleach solution averaged 110 degrees fahr. The chlorine and the soda were allowed to recombine and the temperature was so high that chlorates were formed.

The bleach was applied directly in front of the inlet valve of one of the pre-filters operated at a 20 million gal. rate, or ¼ normal. The conclusions were, in part, that the bacterial efficiency of the filter was considerably less than that of filters operated at four times the rate without treatment.

Hypochlorite was again used in December, 1910. Due to the fact that the bacterial efficiency of slow sand filters decreases materially in cold weather, and the fecal organism, B. coli communis, was present in the filtered water, it was decided to use chloride of lime to disinfect the water in the filtered water basin.

The plant consisted of two cedar mixing tanks, 5 ft. in diameter and 4 ft. deep, and one solution tank of the same dimensions, and a yellow pine orifice tank, cubical in shape, 2 ft. on a side.

The cedar tanks were perforated by the bleach and were later lined with cement, decreasing the capacity from 500 to 380 gal. A concrete orifice tank was substituted for the wooden one. Mixing is done by hand, by two laborers using paddles, the period of agitation being about an hour. Analyses are made of the solution in the tanks, of the powder, and of the sludge.

At the start 540 lb. of powder were used for 200 million gal. of water. The treatment was continued for the first four months of 1911, when it was stopped until December.

During the five months of 1911, when bleach was used, the number of positive tests for B. coli in the filtered water was as follows:

1911.

	Filtered Water Basin.		Tap at Lardner's Point.	
	Per Cent. + 1 C. C.	Per Cent. + 10 C. C.	Per Cent. + 1 C. C.	Per Cent. + 10 C. C.
January, April, and December	4.0	13.3	2.4	12.9 treated
May to November inclusive . .	14.5	58.0	10.0	48.6 untreated

May to November the efficiency of the filter plant is at its highest and the bacteria count low, averaging less than 20 per c.c.

During 1912 and 1913 the treatment has been continuous and the figures are:

1912.

Filtered Water Basin.					Tap at Lardner's Point.				
No. Tests.	1 C. C. +	Per Cent. +	10 C. C. +	Per Cent. +	No. Tests.	1 C. C. +	Per Cent. +	10 C. C. +	Per Cent. +
364	15	4.1	80	22.0	302	6	2.0	51	16.9

This shows a considerable reduction over 1911, but the results are still too high.

During 1912, when ½ part or more was used, the figures were: Filtered Water Basin, 1 c. c.+, 2.5 per cent.; 10 c. c. +, 14.9 per cent. Lardner's Point, 1 c. c. +, 1.1 per cent.; 10 c. c. +, 9.1 per cent.

For the first seven months of 1913, during which over ½ part has been used continuously, the following figures have been obtained.

For the Filtered Water Basin, out of 212 tests of 1 c. c. but two were positive, or 0.9 per cent.; for 10 c. c., 7 were positive, or 3.3 per cent.; and for Lardner's Point the percentages are .6 per cent. and 6.2 per cent.

This is a reduction from 1910 for 1 c. c. of 12.7 per cent. to .9 per cent., and for 10 c. c., 38.8 per cent. to 3.3 per cent. It must be remembered in this connection that during 1910 the bacteria efficiency was 99.36 per cent.

We consider this most remarkable, showing as a positive proof the value of hypochlorite, especially in strengths of ½ to 1 part powder, corresponding to $\frac{1}{6}$ to $\frac{1}{3}$ part chlorine.

CONCLUSIONS.

As constructed at present, using hypochlorite, the Torresdale filtration plant can and does produce an effluent that is almost entirely free from pathogenic bacteria, that is, perfectly safe to use without boiling or further treating, but one that is not always clear.

A plant constructed as Torresdale, without any sedimentation basin, is utterly unable to cope for any prolonged period with water having a turbidity of over 100, that is, with the slow sand filters operating at a six million rate. When such a condition is reached, the pre-filters fail to do their proportion of work, and the final filters choke badly, allowing fine silt to pass through them. This choking necessitates cleaning for twenty-two hours a day, with 55–58 filters doing the work of 65 and depending on hypochlorite to reduce the number of bacteria and destroy the pathogens, which it does.

Fortunately the periods of turbid water occur but seldom and are of short duration.

The pre-filters should be changed and operated like the coal filters at Steelton, or a sedimentation basin should be constructed, using alum to coagulate the water.

But, to summarize, including the very worst periods the bacterial efficiency of the Torresdale filter plant averages over 99.5 per cent.; the water is clear and sparkling at least forty-eight weeks of the year, and is perfectly safe to drink at all times.

DISCUSSION.

Prof. George C. Whipple.* This is one of the largest filter plants in the world, perhaps the very largest, and up to the present time we have not been able to study the results of its operation. This Association should consider itself fortunate in having these data presented to it. There are many interesting points of detail in this paper.

The frank admission that the preliminary filters have failed to do the work that was expected of them is important but not surprising to those who have studied the theory of their action. These preliminary filters act virtually as sedimentation basins, and it seems to me that it is perfectly natural that they should give a higher efficiency in the summer, when the water is warm, than in the winter when the water is cold and more viscous. That is generally true of sedimentation, and it is also true of filtration. The results shown here at Torresdale follow the theory very closely.

In the analyses of water before and after filtration which Mr. West has given us we find merely average figures arranged by months. This is the common practice, but when I think of the thousands of analyses that must have been made in his laboratory, three times a day at very many different places, and when I compare this very large number with the simple averages by months that he has shown us, it seems to me that a good deal has been lost from the record, and that we are not getting all of the information that we would like to get. This is not true of Mr. West's paper alone; it is true of almost all reports of filter plants that are published to-day. I feel that something is wrong in the way in which we use the information that we accumulate at so much time and expense. What we really want to find out in regard to a filter plant is whether it is operating regularly, whether it is giving good results, day by day, and hour by hour. Monthly averages do not tell us this. It seems to me that it is high time that as engineers we took this matter up and discussed it in all seriousness, to see if we cannot devise some better way of using the information that we are getting than we are doing at the present time. And I think that it would be very fitting for this Association to have a

* Professor Sanitary Engineering, Harvard University.

committee appointed to consider this matter, not only the subject of analyses, but all other statistical facts in connection with the operation of filter plants.* A large percentage of the water that is served to the people of this country to-day is filtered water, so that the subject is one of wide import.

I hope that Mr. West will include in the further discussion of his paper some of the diagrams which he has placed upon the screen this evening, and also some of the photographs and cost data. I am sure we should all be glad to have them in the JOURNAL. We are certainly very much indebted to Mr. West for his valuable contribution to the literature of filtration.

MR. JOHN H. GREGORY.† Mr. West's paper on the Torresdale filter plant is one which is extremely interesting to the speaker, as he was formerly connected with the city of Philadelphia and was in charge of the design of the slow sand filters. There are many interesting points that could be taken up in connection with the design and operation of the plant, but the time at our disposal is too limited to more than consider one or two.

Mr. West has spoken about one method of cleaning filters, that is, scraping and piling, without removing the sand from the filters, and stated that it had been used at Torresdale. It may be of interest to say that the same method was used at Albany, N. Y., in 1899. It was shortly after we started the slow sand-filter plant there, and it was possibly in the second or third run of the filters. The plant at Albany was started up under somewhat similar conditions to those at Torresdale; that is, the plant was not finished, but it was desired to furnish filtered water to the city at as early a date as possible. At that time the sand washers at Albany were not complete, nor was the court entirely paved. The first filter runs had been made and it became necessary to clean the filters. The sand was taken out from several filters and piled in the paved part of the court. In the other filters, as there was no opportunity to store the sand outside, the means was resorted to of scraping and piling the sand in the filters, after which the filters were put back in operation. As far as the speaker knows, that was the first time that this method was used in this country.

* For further discussion on this suggestion and appointment of committee see page 465.

† Consulting Engineer, New York.

At the time that the slow sand filters at Torresdale were designed, the question of whether to build a sedimentation basin or preliminary filters for the preliminary treatment of the Delaware River water had not been definitely settled. The city was then experimenting at the Spring Garden testing station with sedimentation and also with preliminary filters. One of the original schemes considered was the construction of a sedimentation basin, practically out in the river, on the east side of Delaware Avenue and north of the present pumping station, and to pass the water through it before pumping it to the filters. The building of the preliminary filters instead of a sedimentation basin was not decided on, however, until some time after the speaker had severed his connection with the Philadelphia work.

It occurred to the speaker, when Mr. West was speaking about the character of the Delaware River water changing with the swing of the tide, that had a settling basin been built it would have been advantageous to operate it along the lines that the speaker observed when he visited the Antwerp filter plant. The practice there is to pump the water from the river to the settling basin at practically the end of the ebb tide; when the tide turns and comes back up the river they shut off pumping and wait until near the end of the next ebb tide before resuming. By this method of operation they get a very much better character of water to purify. The river from which the water supplied to Antwerp is obtained is more or less polluted at the water-works intake, especially so when the tidal currents are running upstream.

MR. JOHN C. TRAUTWINE, JR. Mr. West's paper refers primarily to the quality of water; but, between the lines, we may read an important message on that question of quantity which is the all-important question, underlying the entire problem of the Philadelphia supply. The merits of this question are so well known to all present that any extended discussion of it here would be inexcusable; but I am tempted to say a word, in view of the suggestions in Mr. West's paper, and especially in connection with what Mr. Gregory has just told us about the operation of the plant at Antwerp.

Referring to the early days of the Torresdale plant (1908), Mr. West uses the significant words: "Quantity became all im-

portant; quality was a decidedly second consideration"; and he tells us that those in charge were glad to take refuge behind the fact that, rich as their effluent then was in impurities, it was a distinct improvement upon the awful stuff which the city fathers forced me to pump while I was in nominal charge of the Philadelphia Water Bureau.

Near the close of his paper, Mr. West says: "We are putting out more water than would supply London," a city with about four times our population. Allowing for difference of legitimate use, between the Londoners and ourselves, we are safe in saying that we are expensively pumping, filtering, storing, and distributing more than twice as much water as our people, with their best efforts, can possibly use and enjoy, more than half of this filtered water being thrown into the sewers unused; and this in spite of the fact that four fifths of our people are using water reasonably, the entire waste being perpetrated by the remaining one fifth, who themselves derive no benefit from the waste.

As a result, the works are strained, night and day, in their efforts to fill a sieve; and the taxpayers are constantly threatened with more big bills for more big works which are not needed; the present works being more than ample (under common-sense methods) for a city twice our size.

Mr. Gregory has just told us that, at Antwerp, the works are shut down during the flood tide which brings polluted water to the intakes, the use of this polluted water being thus avoided. Such a course is impossible with us, because the works must be driven twenty-four hours per day, to avoid shortage. This of course precludes also the making of essential repairs, and the works are therefore undergoing rapid deterioration.

In the matter of quality, the Philadelphia works are incomparably ahead of the conditions which obtained during the dark and gloomy days of my chiefship; but, as to quantity, there has been but little if any improvement; and the pathetic part of it is that there is no need for such a situation.

Those at present in charge of the Department of Public Works have announced their desire to curtail the waste; and the city charter expressly places the direction, control, and administration of the works in the hands of that department, expressly prohibits

the city councils from interfering with or directing the exercise of the executive functions of the department, and expressly commands the city councils to provide for the proper and efficient conduct of the works by the department.

If the city charter means anything, it means that the direction of the public works shall be taken out of the hands of a body of butchers, bakers, candlestick makers, and bartenders, and placed under the control of men presumably qualified, by education and experience, to understand the problems involved.

And yet the city councils, disobeying the city charter, and usurping the functions given by the charter to the department, do interfere with and presume to direct the exercise of those functions, and they do not provide for the conduct of the works by the department.

We are told that we must submit to the deplorable results of the prodigious and preposterous waste, because, forsooth, city councils forbid the department to restrict the waste in its own way, and refuse to provide the necessary funds.

I long to see the administration go into court, dragging councils in by the nape of the neck, and compelling them, by mandamus, to perform the duties imposed upon them by the city charter.

I understood Mr. West to say that he was not prepared to give us the costs of filtration under the present method used. Is there any one else present who can give us that?

Mr. Joseph S. V. Siddons. I think I can give you that information. The cost of removal for the first year, 1908, was \$2.44 a million gallons; for the piling, 57 cents a million gallons; the Brooklyn method was \$1.64, the Nichols method \$1.96; the rake filters cost us 18 cents a million gallons. In 1909 the Nichols method had dropped to 81 cents a million gallons, the removal to 67 cents, and the first rake was 7 cents a million gallons, the second rake 11 cents, and the third rake 15 cents. The piled filters were 54 cents a million gallons; and then seven filters were raked after they had been piled. For this we got the water at 18 cents a million gallons. In 1910 the Nichols method was 91 cents a million gallons and 38 cents per cu. yd.; the removal was \$1.21 a million gallons and 41 cents a cu. yd. of sand. First rake cost 8 cents; second rake cost 13 cents; third rake cost 19 cents. At

that time we started to resand with the Nichols machines and that cost us 25 cents a cu. yd. during that year. In 1911 the Nichols method was still 38 cents a cu. yd., with $1.04 per million gallons, and the removal 54 cents a cu. yd. and 87 cents per million; the piling was 44 cents. First rake cost 6 cents, second rake cost 12 cents, resanding cost 31 cents per yd. The reason for the increase on resanding was due to the fact that in the case of the first filters that we resanded by the Nichols method the sand was taken from the bins right in front of the doors, and of course we had a longer throw from our sand bins into our filters. In 1912 we had $1.28 for the Nichols method and $2.13 for removal. And, by the way, the reason of that high cost for removals was that we did not take more than 2 in. of the penetration from our filters. We had at that time (1912) penetrations as great as 16 in., although the average was about 12 in. On the rake filters the first rake cost 5 cents and the second rake 9 cents. We did not undertake to rake the third time in 1912, because we found that the second rake was not giving us what we would expect from those filters. The average at that time was forty-five million gallons per filter, giving us only fourteen days' run. Instead of doing that, we piled the filters; some of our filters we piled the second time. We spaded one, two, and three times. As Mr. West said, we used every method that it was possible to in order to get the water. The resanding, which was done with the Nichols machines, was 26 cents a million gallons.

To summarize those figures and to take them for all four years, the cost of the Nichols method was $1.09 a million gallons and 37 cents a cu. yd.; the removal method cost $1.51 a million gallons and 40 cents a cu. yd.; the resanding was 25 cents a cu. yd. The raking up until the beginning of 1912 cost us about $5.50 per filter; but at that time we devised another method, that is, we changed the method of raking, and brought it down to $4 per filter. This gave us 5 cents for first rake, 8 cents for second rake, and 32 cents for third rake, for the average for the four years, although we did get as low as 3 cents per million gallons for first rake.

Possibly it would be interesting to compare the different methods for yields. At the start, as Mr. West said, the average was 47

million gallons filtered daily. The Brooklyn method average was 19 million gallons; the average for removal was 74 million gallons, and 379 million gallons for the maximum. The average was 150 million gallons for the Nichols method, which was double any of the other methods, and 569 million gallons for one filter from the Nichols method. That was a run of one hundred and forty-eight days. We consider that a rather remarkable run — 569 million gallons. The spaded filters gave us 51 million gallons for an average and 90 million gallons as the maximum. Filters raked once, 85 million gallons; filters raked twice, 52 million gallons; filters raked three times, 41 million gallons; piling, 35 million gallons. Of course, as one of the gentlemen said, these figures are averages, and in order to get down to a detail it requires rather a lengthy article to get these things out. I believe that Mr. Hardy, in charge of the Washington plant, had one in the Journal of the American Society of Civil Engineers* some time ago, and his was quite a lengthy table. But I will say that our filters for forty-eight weeks in the year (or very nearly all of that time) gave us filtered water at an average of about 99.2 removal, with a bacteria count of less than one hundred.

Mr. John A. Kienle.† Mr. President, the speaker has been much interested in the paper which Mr. West has presented, and also its discussion, particularly that portion dealing with the question of economical methods of filter sand washing. As chief engineer of the Water Department at Wilmington, Del., the speaker had considerable experience with the method of cleaning filter sand by the use of Blaisdell's Filtration Company's washing machines. This method is strictly mechanical and a full description of it can be obtained by reference to the annual reports of that department. At that time the speaker's recollection in regard to the cost per million gallons of the Blaisdell method of cleaning is that it was about $1.10 in the second year of the operation of the plant, which compares with what Mr. Siddons has said with regard to the Nichols method of cleaning. During the time I was connected with that plant I watched very closely the articles appearing in the engineering papers regarding the cost of filter cleaning, particu-

* Trans. Am. Soc. C. E., vol. lvii, 307; vol. lxxii, 301.

† Sanitary Engineer with Electro Bleaching Gas Company, New York.

larly of the slow sand type, and it is my present recollection that there were no lower costs than those obtained at Wilmington by the use of the Blaisdell machine.

The Nichols method has been discussed quite extensively, and one feature in connection with it which the speaker discussed with a number of gentlemen is the question of the loss of fine sand due to its escape with the turbid water during the washing process. It is the speaker's belief that it would be of interest to the members of the Association to have Mr. West embody in his summary of remarks for the discussion a statement regarding the effect of the loss of this fine sand. In one instance, in discussing this question with a gentleman who was in charge of another plant, there was some thought that this loss of fine sand would have to be replaced. Whether that is actually the case or not, however, is open to question.

The speaker was interested also in Mr. West's remarks regarding the organic matter, particularly his statement to the effect that this subject had not been thoroughly studied and presented before the several associations; that is, the effect of the organic matter. He distinctly recalls that, shortly after the beginning of the operation of the Wilmington plant (it had been in operation something like three months, through the early spring), in March during a very warm period the water from the sedimentation basin after some three or three and a half days' storage had as much as two thousand microscopic organisms per cubic centimeter. And this water was discharged on to the filters at the time when we were not making regular microscopic examination of the water. Inside of seventy-two hours the entire plant was out of service. This would have resulted in delivering the raw water from the reservoir to the city if it had not been that the Blaisdell machine came to our assistance. With it we were able to wash a one-third acre bed in about four hours, and get it back in service again. That really shows one advantage of this method of cleaning. In addition, the method has the advantage of reducing the first construction cost by reason of the filter area required. That is to say, the time out of service of any section of a filter plant increases the total area of that plant very materially, in order to have ample reserve during the washing period. This reserve area is very

materially cut down by the use of the Blaisdell method. The speaker would not want to say positively (it is a matter of record in the Wilmington Water Department reports), but it is his recollection, that there was only five per cent. of the time that the filters were out of service, while in the ordinary slow-sand plants, with the ordinary methods of cleaning, this time out of service is very much more than that I have stated. The method of raking the filters, which has within the last three or four years come into use, can also be adopted with the Blaisdell machine. At Wilmington we found that following a washing with the machine the yield was not as great as following a raking with the machine. In order to machine rake the filters, the water was drawn off the surface of the bed, the machine being then passed over the bed, the teeth through which the water is ordinarily injected in the washing process effecting the raking very much more thoroughly on the bed and to a greater depth than can possibly be obtained by hand rakes; in fact, it is very much more uniform. The speaker's recollection is that the increased yield due to this mechanical raking was almost 100 per cent. In other words, a yield that might be something like thirty million gallons per bed would be raised by washing to possibly as much as sixty million gallons.

Mr. J. S. V. Siddons (*by letter*). The following tables show the actual labor cost per million gallons and per cubic yard of sand washed. By the actual labor cost, is meant, the cost of cleaning from the time the sand-run door is opened until the laborers are out and have moved the washing machinery to the next filter to be cleaned. This also includes the cost of raw water used for washing sand, for which we charge ourselves $5 per m.g.

The laborers receive $12 per week of 44 hr., or 27.3 cents per hour.

The total cost of operation per million gallons filtered for 1912 is shown in the following table; this includes 2 cents per m.g. for clerical force on filter records at City Hall; also 12 cents per m.g. for coal used for pumping pre-filtered wash water used at the preliminary filters, power to operate blowers at the pre-filters, and coal used to heat the laboratory and treatment house.

These figures include all the materials used in the operation of the plant, also cost of bleach used in the hypochlorite plant. The cost of pumpage is additional to the above.

TABLE 15.

	Number of Filters.	Yield, Million Gallons.						Days Run.			Cost, Dollars.			
		Total.	Max.	Min.	Av.	Acre.	Rate.	Max.	Min.	Av.	Total.	Filter.	M.g.	Cu.yd. Sand.
1907														
Start	55	......	60	18	37	49	1.8	71	11	28	....	.....	...	...
Brooklyn, 07–08	609	11 345	67	4	19	25	1.8	49	6	14	19 521.44	32.09	1.72	...
1908														
Start	10	......	73	47	59	79	1.2	77	63	65	....	.....	...	...
Remove	282	11 028	80	19	39	52	2.6	45	10	20	26 907.30	95.42	2.44	.40
Piling	530	18 321	69	17	35	46	2.4	42	10	19	10 541.45	19.89	57	...
Brooklyn	216	3 921	61	4	18	24	1.6	42	6	15	6 407.68	29.67	1.64	...
Nichols	5	365	108	42	73	97	2.2	60	30	45	715.86	143.17	1.96	.47
Raked	24	948	66	24	39	52	2.2	37	16	23	174.40	7.27	.18	...
Resand	27	......	...	...	...	...	...	...	...	...	8 678.88	.....	...	.24
	1 057	34 583	...	...	33	44	2.3	...	...	19	53 425.57	.....	1.54	.51
1909														
Nichols	229	28 244	519	51	123	164	4.5	122	16	34	22 942.85	100.19	.81	.44
Remove	62	11 973	379	37	193	257	4.3	105	11	60	8 027.21	129.47	.67	.34
Rake 1	260	20 828	280	20	80	107	5.3	75	6	20			.07	...
Rake 2	151	8 492	116	17	56	75	4.4	37	7	17	2 839.61	5.93	.11	...
Rake 3	68	2 775	73	17	40	53	4.8	24	5	13			.15	...
Piled	77	3 249	142	12	43	57	3.6	57	4	16	1 761.67	22.82	.54	...
Piled and rake	7	560	198	43	80	107	4.6	49	12	23	100.29	14.32	.18	...
Resand	37	......	...	...	...	...	...	...	...	...	10 353.68	.....	...	.23
	854	76 121	...	...	87	116	4.6	...	...	25	46 025.31	.....	.61	.38

1910														
Nichols	232	45 196	569	68	195	260	4.5	148	27	58	41 177.72	177.49	.91	.38
Remove	71	8 390	291	56	118	157	4.4	91	20	35	10 151.76	142.98	1.21	.41
Rake 1	236	19 927	246	25	84	112	4.3	60	11	26			.08	...
Rake 2	107	5 618	116	16	52	69	4.1	33	8	17	2 255.55	6.50	.13	...
Rake 3	4	141	47	23	35	47	3.4	23	10	14			.19	...
Resand	14	......	...	...	...	...	...	...	...	...	3 466.33	.....	...	.25
	650	79 272	...	...	122	163	4.5	...	...	36	57 051.36	.....	.88	.39
1911														
Nichols	265	42 465	401	49	160	213	4.3	102	20	50	44 228.11	168.89	1.04	.38
Remove	20	1 625	195	50	81	108	4.1	63	19	27	1 418.97	70.98	.87	.54
Rake 1	259	25 253	237	38	98	130	4.8	72	11	26			.06	.
Rake 2	84	4 136	120	21	49	65	4.6	31	8	14	2 008.34	5.84	.12	...
Rake 3	1	53	53	53	53	71	3.7	19	19	19			.11	...
Piling	3	167	72	38	56	75	5.3	19	10	14	74.64	24.88	.44	...
Resand	14	......	...	...	...	...	...	...	...	...	3 376.65	.....	...	.31
	632	73 699	...	...	117	156	4.5	...	...	35	51 106.71	.....	.69	.38
1912														
Nichols	303	38 866	289	30	126	168	4.3	80	11	39	49 704.63	164.04	1.28	.35
Remove	82	5 251	187	10	64	84	5.0	55	4	17	11 163.06	136.14	2.13	.43
Rake 1	257	21 270	182	3	83	111	5.0	50	2	22	1 268.72	3.93	.05	
Rake 2	66	2 987	79	16	45	60	4.3	24	6	14			.09	
Piling 1	37	1 249	70	3	34	45	5.0	18	2	9	1 161.24	27.65	.82	
Piling 2	5	198	50	20	40	53	4.1	22	7	13			.70	
Spading 1	50	2 700	90	11	54	72	4.2	22	4	17			.29	
Spading 2	14	590	65	30	42	56	5.1	16	9	11	1 010.05	15.54	.37	
Spading 3	1	32	...	...	32	43	4.8	...	...	9			.49	
Resand	18	......	...	...	...	...	...	...	...	...	4 970.57			.26
	815	73 143	...	...	90	120	4.6	...	...	26	69 278.27	.....	.95	.37

TABLE 15.—*Continued.*

SUMMARY, 1907–1912.

	Number of Filters.	Yield, Million Gallons.						Days Run.			Cost, Dollars.			
		Total.	Max.	Min.	Av.	Acre.	Rate.	Max.	Min.	Av.	Total.	Filter.	M.g.	Cu.yd. Sand.
Start	65	2 654	73	18	47	63	1.9	77	11	34	....	.....	...	...
Brooklyn	609	11 345	67	4	19	25	1.8	49	6	14	19 521.44	32.09	1.72	...
Remove	517	38 267	379	10	74	99	3.6	105	4	27	57 668.30	111.54	1.51	.40
Nichols	1 034	155 136	569	30	150	200	4.4	148	11	45	158 769.17	163.22	1.09	.37
Rake 1	1 036	88 226	280	3	85	113	4.7	75	2	24	....	.....	.05	...
Rake 2	408	21 233	120	17	52	69	4.6	31	6	15	8 546.62	*5.56	.08	...
Rake 3	73	2 969	73	17	41	55	3.9	24	5	14	....	.....	.32	...
Piling	652	23 184	167	3	35	47	2.6	19	2	18	13 539.00	20.76	.58	...
Piling and rake	7	560	198	43	80	107	4.6	49	12	23	100.29	14.32	.18	...
Spade	65	3 322	90	11	51	68	4.5	22	4	15	1 010.05	15.54	.37	...
Resand	110	......	...	...	...	...	...	...	...	...	30 846.11	280.42	...	.25
	4 466	346 896	...	...	78	104	4.5	...	...	26	290 000.98	.....	.84	.36

* 1912, 4.00.

Cost of Operating Final Filters per m.g. Filtered.

Office	$0.08
Filter attendant	.13
Cleaning sand	1.00
Labor on grounds	.01
Maintenance and repairs	.10
Laboratory	.16
Lighting	.05
Treatment	.09
Janitor and watchman	.02 = $1.67

Cost of Operating Preliminary Filters per m.g. Filtered.

Filter attendant	$0.14	
Labor on grounds	.02	
Maintenance and repairs	.08 =	.24
Total cost per million gallons		$1.91

The total cost per million gallons filtered since operation was started has been as follows:

Year.	Pre-Filter.	Final Filter.	Total.
1907*	....	....	$3.75
1908	....	....	2.80
1909	$0.26	$1.44	1.70
1910	.30	1.52	1.82
1911	.28	1.38	1.66
1912	.24	1.67	1.91
1913†	.22	1.50	1.72

* Last six months. † First six months.

Table 16 gives the amount of sand handled.

TABLE 16.

Cubic Yards of Sand Handled.

	Nichols Method.		Removal Method.		Resanding.		Total.
	Totals.	Av. per Filter.	Totals.	Av. per Filter.	Total.	Av. per Filter.	
1908	1 529	306	67 335	239	36 162	1 339	105 026
1909	52 567	229	23 227	375	45 016	1 217	120 810
1910	109 092	470	24 707	348	13 716	980	147 515
1911	120 257	452	2 655	133	11 021	787	133 933
1912	141 136	466	26 595	324	18 912	1 056	186 643
	424 581	411	144 519	279	124 827	1 134	693 927

The following figures show the cost of handling sand and some wash-water data.

Average cost to scrape one cu. yd. of sand	$0.15
Average cost to wash one cu. yd. of sand	.20
Average cost per cu. yd. to move machinery to next bed	.02
Total average cost	$0.37
Volumes of water to sand	6
Cu. yd. of sand per m.g. filtered	1.9
Average cu. yd. of sand washed per hr. (Nichols method)	7
Wash water per cent. of total yield, preliminary	.6%
Wash water per cent. of total yield, finals	.4%
Wash water per cent. of total yield, total	1.0%

NOTES ON WATER WASTE PREVENTION WORK IN NEW YORK CITY.

BY WILLIAM W. BRUSH, DEPUTY CHIEF ENGINEER, BUREAU OF WATER SUPPLY, DEPARTMENT WATER SUPPLY, GAS AND ELECTRICITY, NEW YORK CITY.

[*Read September 10, 1913.*]

Conservation of resources and elimination of waste are to-day receiving preferential attention by both municipal and private corporations, and in the past three years New York City has accomplished results along these lines in her water-supply system, unequaled, it is believed, by any other municipality. In 1910 New York had a per capita consumption of 111 gallons, which was lower than that of seven out of the first ten American cities, as shown by the following table:

City.	Estimated Population, 1912.	Daily Water Consumption per Capita. 1912.	1910.*
New York	5 053 000	100	111
Chicago	2 350 000	199	235
Philadelphia	1 600 000	200	203
St. Louis	710 000	118	109
Boston	718 900	125	130
Cleveland	660 000	111	102
Baltimore	569 000	128	115
Pittsburg	517 000	236	197
Detroit	566 000	185	177
Buffalo	450 000	310	321

Even with this comparatively low consumption, during less than three years water-waste work, New York has reduced her total consumption from 525 m.g.d. to 486 m.g.d. If allowance be made for the normal three per cent. yearly growth in population, this reduction is equivalent to 90 m.g.d., or more water than the present supply of St. Louis or Boston, with their population of nearly three quarters of a million.

As this reduction has come from a net expenditure of about one hundred thousand dollars and a gross expenditure of less than one hundred and fifty thousand dollars, the efficiency of the methods

* The figures given are, as far as possible, for the year 1910.

used cannot be questioned, and an outline of the work should be interesting to water-works officials.

Boroughs of Manhattan and The Bronx.

REASONS FOR UNDERTAKING WATER WASTE PREVENTION WORK.

The Boroughs of Manhattan and The Bronx obtain their supply from the watersheds of the Croton, Bronx, and Byram rivers. The continuity of the supply is absolutely dependent upon stored waters, as the run-off of the rivers is, at times, less than the evaporation.

In the spring of 1910, all the available reservoirs in the Croton Valley were full, and water wasted over the New Croton dam up to May 17, when there were 88 690 million gallons, stored in the nine reservoirs and six ponds which are available to hold the water from the 360 square miles that constitute the Croton shed. In the Bronx and Byram shed, covering 22 square miles, there are four reservoirs and ponds, holding 4 195 million gallons, and these were also full. The unprecedented dry season, commencing about July 1, 1910, resulted in a depletion of the stored water in the Croton basins, amounting to 50 583 million gallons by February 28, 1911, when the storage was only 38 107 million gallons. At this time there was little or no snow on the ground and no reasonable hope of heavy spring run-off to replenish the depleted storage.

The consumption at this time was running over 330 m.g.d., and the recorded flow for the Croton River from the year 1868 to 1910 showed that if this rate of consumption continued, and the run-off was no lower than that previously recorded, all the reservoirs would be empty by September. This would mean that there would be practically no water available for a community of three million people, as the flow of the river after a dry summer would be only a small fraction of the normal consumption from the Croton system.

The paralyzing of the industries of the greatest manufacturing city in America, the suffering of the people, and the danger to property and health that would result from a stoppage of the water supply even for a few days' time, constituted a menace to the welfare of the city so great that the Commissioner of Water

Supply, Gas and Electricity, Hon. Henry S. Thompson, immediately commenced, through the public press, to inform the citizens of the condition of the water supply and the need for conserving it. This publicity campaign was productive of results as shown by a reduction in consumption in the month of May amounting to 26 million gallons daily, as compared with the same month of 1910, allowing three per cent. for the normal yearly increase in population and consumption. As the dry weather continued, more radical measures were deemed necessary, and in May it was recommended that the following steps be taken:

RECOMMENDATIONS TO CONSERVE WATER SUPPLY.

1st. Printed notices be delivered at every building in Manhattan and The Bronx, stating the need for stopping waste and calling attention to the fine which the commissioner might impose if the waste was not stopped.

2d. House-to-house inspection to be made by a special corps.

3d. Pitometer work to be undertaken along the river-front, to detect leaks in mains or services.

4th. Surveys to be made and plans drawn for a temporary source of supply of about 50 million gallons daily capacity.

These recommendations were approved and the following notice was printed in English, Italian and Yiddish:

PRINTED NOTICE TO STOP WASTE OF WATER.

IMPORTANT.

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the Department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks of toilets, faucets, and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited.

It is hoped that you will do everything in your power to stop all unnecessary use of water so that we may avert as much as possible a situation which would be most serious.

HENRY S. THOMPSON,
Commissioner.

One hundred and fifty thousand copies of the above were delivered between June 6 and June 16, 1911, as follows:

1st. One hundred and forty-five thousand copies were delivered on the premises, without folding.

2d. In order to reduce waste in large buildings of various kinds, where the consumption of metered water was very great, and where the department did not intend to make an actual inspection, 4 855 notices were placed in envelopes and addressed to the owner, manager, superintendent, engineer, or janitor of large office buildings, apartment houses, department stores, steam plants, and delivered to the individual in charge.

3d. Where the premises to be notified were outside of the delivery limits of the private concern that was doing this work, notices were mailed, the total number of notices delivered in such manner being 145.

The following table shows the weekly consumption in June in Manhattan and The Bronx and in Brooklyn. As house-to-house inspection did not commence until the middle of June, and less than ten per cent. of all premises were covered in that month, the reduction in consumption noted must have been mainly due to the printed notices:

Daily Consumption during June, 1911, Boroughs of Manhattan and The Bronx and Brooklyn.

Week Ending	Million Gallons. Manhattan and Bronx.	Brooklyn.
June 3	283	139
June 10	292	137
June 17	279	135
June 24	289	139
July 1	282	142
Average	286	139
The corresponding figures for June, 1910, were	329	139

There was an evident reduction in consumption following the receipt of the notices, and this reduction increased during the month of July, the total reduction being estimated at about 25 m.g.d., or nearly nine per cent. of the supply in Manhattan and

The Bronx. Assuming that the reduction in waste would gradually lessen and entirely disappear in two years,* the total amount of water saved would be over 9 000 million gallons. As the cost of printing and distributing the notices was $1 388, the resultant cost was $0.15 per million gallons saved, or about one quarter of one per cent. of the average cost of water distributed in New York City.

INSPECTION OF BUILDINGS.

For the house-to-house inspection work a corps of about one hundred and fifty men was employed, there being on an average one clerk at $900 per annum for every four inspectors at $1 100 per annum. The inspectors worked in squads of from fifteen to twenty, in charge of two regular department inspectors. Every building was thoroughly examined, an average day's work of eight hours covering ten buildings.

After the inspection of the premises a notice was mailed by the department, addressed to "The owner or occupant of the premises," calling attention to the leaks found, and notifying the owner to make the necessary repairs to the leaky fixtures, the said form of address being approved by the corporation counsel as a legal notification. Three days were allowed from the date the notice was mailed before a reinspection was made, and if it was found that more than 50 per cent. of the leaky fixtures which had been discovered upon the first inspection had not been repaired, a fine of $2.00 was imposed. After an interval of about a week the premises were again inspected, and if the leaks had not been repaired an additional fine of $2.00 was imposed and this procedure was followed until fines, in some cases, had been imposed as many as seven times on the same premises. Where it was found, after several inspections, that the owner did not occupy the premises in question, his name and address was obtained and an individual notice sent to him, stating that if the leaks on the premises were not repaired, the water would be shut off after three days from the date of notice. In no case was this extreme penalty resorted to;

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*This period of time is used simply as a basis of computation, the exact time required for the leakage to return to the amount existing prior to commencing water-waste work being unknown. It is estimated that at the present time, which is just two years after the house-to-house inspection, the reduction in consumption is about fifty per cent. of that shown immediately after the active campaign was stopped.

although in one case the department men had commenced to dig up the street in front of the premises to shut off the water, when the owner appeared and made immediate arrangements for repairing the leaks on the premises, after paying $9.00 for the work done by the department force in making preparations to shut off the water. The fines imposed became, under the laws of New York, a lien on the property, and therefore readily collectible. Fines were rebated when a satisfactory reason was given, showing inability to comply with the department order within the time allowed.

House-to-house inspection was carried on actively during July, August, and September, and then, owing to the crisis having passed, the force was materially reduced and finally disbanded at the end of the year.

The premises inspected were grouped in districts covering about one hundred city blocks, although the size of the districts varied materially. Pitometer gagings were made immediately before the inspection was commenced in each district, and immediately after the final inspection was completed.

These gagings indicated, as shown by Table 1, that the inspectors saved a maximum of 20 per cent. and a minimum of 2 per cent., with an average of 12.2 per cent., out of a total measured consumption of 175 m.g.d., which is 60 per cent., of the total consumption. The extent of the leakage found, even after the reduction due to the printed notices, is shown by Table 2, from which it will be seen that the number of leaky fixtures averages nearly three to each building. The estimated net cost of this inspection and pitometer work was about $60 000, after the fines were deducted, and even assuming that the leaks then stopped would gradually develop again so that the full amount of leakage reappeared in two years' time, the cost per million gallons would be about $7.70. Assuming an average of one hundred inspectors employed, the amount saved per inspector was 0.21 of a million gallons per day; but if the work had been spread over a longer time, the average per inspector would have been higher, as the cumulative effect of the longer period of work would be shown to the inspector's credit, while the cost would have remained about the same per million gallons.

TABLE 1.

SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN MANHATTAN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

District.	Character.	Daily Consumption before Inspection. Gallons.	Daily Consumption after Inspection. Gallons.	Daily Saving. Gallons.	Saving. Per Cent.
1	Tenement	8 284 000	6 600 000	1 684 000	20
2	Dense East Side tenements	11 444 000	10 613 000	831 000	7
3	Low-class tenements and apartments	14 823 000	12 710 000	2 113 000	14
4	High-class resident district	12 737 000	11 410 000	1 337 000	10
5	Dense East Side tenements	10 301 000	8 680 000	1 621 000	16
6, 8	Tenements and apartments	14 685 000	14 057 000	628 000	4
7	Medium-class apartments	13 378 000	10 894 000	2 484 000	18
9, 12	Medium-class apartments	13 660 000	12 400 000	1 200 000	9
10	High-class apartments	5 655 000	4 664 000	991 000	17
13, 14	High-class apartments	22 181 000	21 690 000	491 000	2
15	Hotel and theater district	29 482 000	23 559 000	5 923 000	20
17	Tenements and apartments	7 360 000	6 234 000	1 126 000	15
18	Business and warehouse district	10 790 000	9 944 000	846 000	7
Total		174 780 000	153 505 000	21 275 000	12.2 aver.

$$\text{Saving } \frac{21\,275\,000}{174\,780\,000} = 12.2 \text{ per cent.}$$

Cost of pitometer gagings	$22 950.00
Cost of inspectors, clerks, etc.	58 150.00
Total cost	$81 100.00

TABLE 2.

MANHATTAN—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JUNE TO DECEMBER, 1911.

Months.	Number of Inspectors, Average per Day.	Number of Clerks for Office Work, Average per Day.	Number of Premises Inspected.	Number of Leaks Found.	Per Cent. Premises having Leaky Fixtures.	Number of Premises Re-examined.	Number of Fines Imposed for Failure to Repair Fixtures.	Amount of Fines Imposed.
1911.								
June	87	13	12 834	47 370	75	2 716	303	$606.00
July	105	25	18 644	56 107	69	21 405	4 496	8 992.00
August	114	21	23 893	48 419	60	17 753	2 175	4 358.00
September	77	21	10 852	33 100	70	17 366	2 510	5 020.00
October	35	24	4 109	7 058	48	8 803	1 823	3 646.00
November	18	13	1 621	3 413	47	5 215	299	598.00
December	7	4	418	1 768	56	2 233	245	490.00
Total			72 371	197 235		75 491	11 855	$23 710.00*

* A small percentage of these fines were rebated.

Fig. 1.

Manhattan.

Partially Blown Joint. Leakage 29 000 Gallons per Day.

Fig. 2.

Brooklyn.

A Blown Joint on 4-in. Hydrant Branch.
Leakage 300 000 Gallons per Day.

LEAKAGE IN STREET MAINS AND SERVICES.

To stop waste from leaks in mains outside of buildings, surveys were made with the pitometer, the force employed consisting generally of an engineer in charge, two assistants, and six skilled and unskilled laborers. This work, especially that along the waterfront, was commenced in September, 1910, and carried on almost continuously until December, 1912, the only interruption being when the entire force was used in connection with pitometer gagings of districts covered by house-to-house inspection in the summer of 1911. The leaks discovered were generally from blown joints, broken pipes, and broken or split house services. The character of leaks is shown on Plate XXXI. The total amount of leakage checked by this work amounted to 16 672 000 gal. daily. In connection with the waterfront work there have been over 16 miles of river front examined, containing about 84 miles of mains, with a measured flow into districts of about 40 m.g.d., and leaks were stopped amounting to 10 m.g.d., of which 5.7 million gal. were found in submerged pipe lines.

The cost of this work was $19 000, and if it be assumed that, on an average, the leaks stopped would have been discovered by the regular maintenance force in ten years, the cost of saving this water would be about $0.50 per million gallons. This cost is based upon a sinking fund of 8.7 per cent. annually, and interest at the rate of 4.3 per cent. The leaks on the submerged lines were very large in proportion to the amount of time spent in locating and stopping the same, and therefore in estimating the cost per million gallons for saving the water, it would be reasonable to omit such large leaks. Assuming that the money spent represented the cost of stopping leaks amounting to 4.3 million gallons daily, the cost would be about $1.30 per million gallons.

Table 3 shows the results accomplished in the way of reducing leakage by appeals through the press, printed notices to stop leaks and unnecessary use of water, house-to-house inspection, and stopping leaks from mains and service pipes. In this table the amount credited to each cause is necessarily approximate, with the exception of the leaks from mains and defective services, but the table, nevertheless, gives some adequate idea of the relative

TABLE 3.

REDUCTION IN CONSUMPTION — MANHATTAN AND THE BRONX — 1911.

(Million gallons daily.)

Consumption.			Estimated Consumption assuming Increase 3%, Equivalent to Rate of Increase in Population, 1911.	Estimated Reduction in Consumption.				Total.
Month.	1910.	1911.		Press Publicity.	Printed Notices.	House-to-House Inspection.	By Stopping Underground Leakage.	
January	335	334	345	0	—	0	4	11
February	336	331	346	0	—	0	4	15
March	327	327	337	4	—	0	6	10
April	326	320	336	10	—	0	6	16
May	326	310	336	18	—	0	8	26
June	329	286	339	20	21	3	9	53
July	342	287	352	20	27	9	9	65
August	336	275	346	20	26	16	9	71
September	335	277	345	18	22	18	10	68
October	332	278	342	13	20	20	11	64
November	321	271	331	11	17	21	11	60
December	333	283	343	11	17	21	11	60

effectiveness of the means employed to reduce waste and unnecessary use of water.

METERED CONSUMPTION.

The metered consumption, which amounts to about 30 per cent. of the total for Manhattan and The Bronx, or 90 m.g.d., has remained practically constant during the water-waste work, the increase being only that due to normal growth. The reduction has, therefore, been confined to the unmetered consumption, and represents, as a maximum, a reduction of thirty per cent. of said consumption. The per capita consumption in Manhattan and The Bronx, before and after the water-waste work, was as follows:

Time.	Average Daily Consumption, Million Gallons.		Average Daily Consumption, Gallons per Capita.	
	Total.	Metered.	Total.	Excluding Metered Consumption.
January—December, 1910	331	84	120	90
January—June, 1911	318	89	112	81
July —December, 1911	279	89	98	67
January—December, 1912	303	90	104	73
January—June, 1913	304	90	102	72

In New York all water used for business purposes is metered, and the metered services in 1912 in Manhattan and The Bronx numbered 61 500 out of an estimated total of 92 300 metered services in the five boroughs.

It will be seen that, excluding metered consumption, the per capita consumption is low for a large city, but still materially above what is probably necessary for domestic consumption, indicating that the amount of leakage still remaining is large in total quantity although probably difficult and comparatively expensive to eliminate.

PER CAPITA CONSUMPTION.

The per capita consumption for the last twenty years is shown on Table 4.

From this table it will be seen that the drop in per capita consumption amounted to 30 per cent., i. e., from 134 gal. to 102 gal. This reduction commenced in about 1906, but the cause is not clear prior to the water-waste campaign in 1911. It was probably due, in a great measure, to business depression, New York City, as the financial center and the largest manufacturing city in the United States, very promptly feeling any dullness in trade and resulting reduction in manufacturing.

WATER-WASTE WORK IN THE FUTURE.

With the excellent and exceptionally low-cost results obtained, the continuance of the waste prevention work would be expected, but owing to the character of the Croton system, it was found to be

TABLE 4.

Per Capita Consumption, 1892–1913, Manhattan and The Bronx, and Brooklyn.

(Gallons daily.)

Year.	Manhattan and The Bronx.	Brooklyn.
1892	91	74
1893	96	79
1894	99	72
1895	100	75
1896	109	85
1897	115	88
1898	117	88
1899	123	88
1900	130	88
1901	129	86
1902	129	86
1903	128	85
1904	132	90
1905	134	91
1906	133	96
1907	131	101
1908	126	100
1909	122	95
1910	120	97
1911	105	92
1912	104	91
1913 *	102	78

* First 6 months.

TABLE 5.

BOROUGHS OF MANHATTAN AND THE BRONX, AVERAGE DAILY CONSUMPTION, 1903 TO MARCH, 1913, INCLUSIVE.

(Million gallons.)

Month.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January	294	300	314	320	340	325	316	335	334	302	292
February	292	310	320	323	353	340	316	336	331	310	306
March	290	299	319	320	344	329	317	327	327	299	301
April	284	294	315	318	329	325	316	326	320	297	304
May	285	296	313	317	323	322	321	326	310	299	307
June	283	307	315	328	328	340	330	329	286	308	314
July	292	300	323	331	334	342	330	342	287	309	
August	287	301	318	316	330	330	329	336	275	305	
September	291	307	318	332	323	329	335	335	277	309	
October	285	305	321	330	322	321	334	332	278	300	
November	284	302	322	326	314	313	322	321	271	297	
December	290	311	323	337	316	309	314	333	283	297	
Average	287	303	318	325	330	327	325	331	298	303	304

uneconomical to pursue waste prevention work by house-to-house inspection after the sufficiency of the supply was demonstrated beyond reasonable question.

With a gravity supply, which is the condition in Manhattan and The Bronx for about 75 per cent. of the consumption, and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn and when a full supply is being drawn from the watersheds. The same force has to be employed to care for the watershed, reservoirs, aqueduct line, and distribution system, so that the operation and maintenance cost is not affected by reduction in water waste. The trunk main capacity is, however, affected by the rate of draft, as said mains, in a large, well-designed system, are normally proportioned to the needs for domestic consumption, with some margin for fire purposes. For about every 20 m.g.d. added to the consumption, a 48-in. main has to be laid; so that for each 20 m.g.d. saved, the laying of a 48-in. main can be eliminated. By taking the average length of trunk main required to deliver water from the end of the aqueduct to the center of distribution, and determining the cost of such a main, the monetary value of water saved can be arrived at, assuming there is no reason to save water to prevent extensions to the supply system, which was the case in Manhattan and The Bronx in 1912. Thus, from the terminal of the aqueduct at 135th Street gate house, Manhattan, to the center of distribution, is estimated at 25 000 ft. The cost of laying a 48-in. main in Manhattan streets is estimated at $18.00 per ft., making the cost of such main $450 000. Assuming the capacity of the 48-in. main to be 20 m.g.d., the cost per million gallons capacity would be $22 500. Assuming interest, sinking fund, and maintenance at 5½ per cent., the cost would be $3.39 per million gallons. As the lateral distributors in the distribution system are of a capacity based almost entirely on fire service requirements, there would be no additional saving for such parts of the system, even if the consumption were to be reduced, say 20 per cent.

For the pumped supply, the cost of maintenance and operation, including sinking fund on equipment, is equivalent to about $10.00 per million gallons.

From the above it is evident that for the present there is no financial return from reducing water waste where the cost of such saving exceeds $10.00 per million gallons in districts where the water is pumped and $3.39 per million gallons in districts where the water is delivered by gravity.

When the Catskill water supply is introduced and has been utilized to such an extent that pumping from the Brooklyn system will have to be resorted to if waste of water is not curtailed, a very different financial problem will be presented, and discussion of this problem at the present time is inopportune.

CONTROL OF LEAKAGE FROM MAINS AND SERVICES.

While financially the house-to-house inspection part of the water-waste prevention work was uneconomical after the fall of 1911, the measurement of flow in mains to detect underground leakage was continued, the force, however, being assigned at times to other work. This work resulted in the discovery and repair, during 1912, of about 33 leaks, divided as follows:

Broken mains..........	5
Joints.................	19
Defective services.......	9

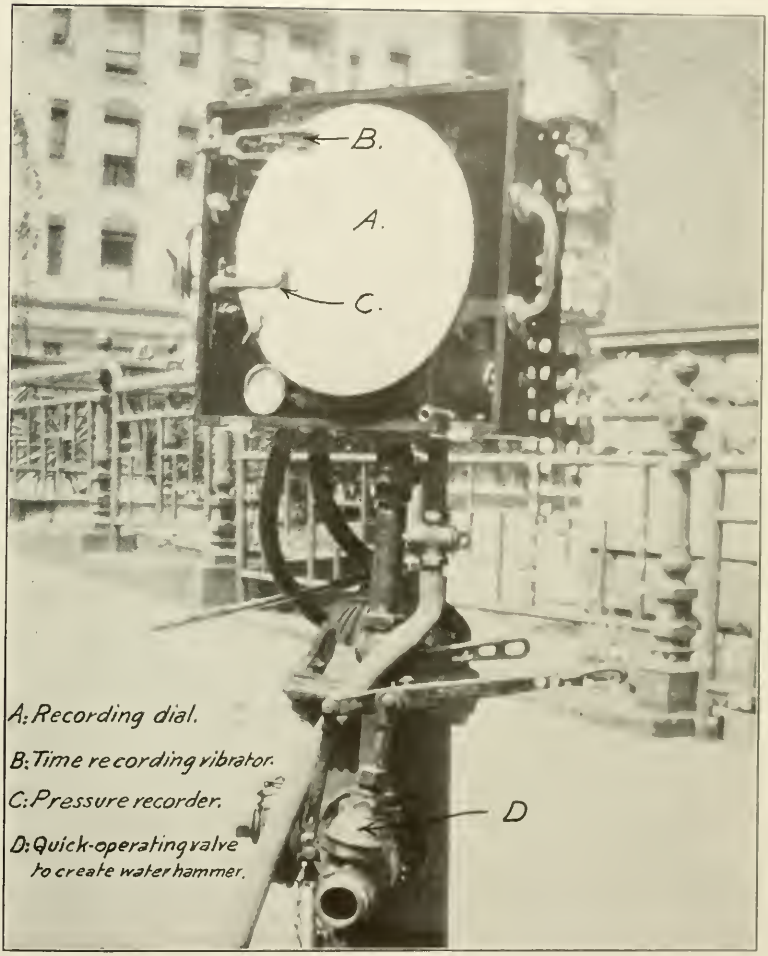
These leaks amounted to 3.8 m.g.d., while the total cost was about $16 000. Assuming that, on an average, these leaks would have been discovered by the regular maintenance force in ten years, the cost of saving the water would be about $1.50 per million gallons. This cost is based on a sinking fund of 8.7 per cent. annually and interest at 4.3 per cent.

The conditions in Manhattan and The Bronx are unusually favorable to the development and continuance of leaks from mains and services outside of buildings, without any indication on the surface. Owing to the rock floor being near the surface, much rock is removed in grading streets and excavating for buildings, the same being used to bring to grade streets crossing hollows. Also, in rock underlaid streets, the water main is usually laid in the sewer trench and the filling offers comparatively free passageway for the leaking waters to reach the sewer. Under the above conditions, leaks amounting to several hundred thousand gallons

daily might continue for years without discovery from the appearance of the surface, and leaks of 100 000 gallons daily have been found only after pitometer measurements have shown unreasonably high flows.

To simplify the location of these leaks and to reduce the cost of such location, the department has recently used a "pulsograph," invented by Mr. N. Akimoff, of Philadelphia, which is shown in Plate XXXII. This instrument is based upon the water hammer experiments made in Russia in 1897–98 and reported in paper by N. Jonkowsky before the Russian Technical Society, April 29, 1898. It consists essentially of a large sensitive pressure recorder having a rapid motion, a tuning fork vibrating at a rate of 200 per second, and a quick-operating valve which is on a blow-off or by-pass pipe.

The instrument is set up by screwing it to a hydrant nozzle, the hydrant being chosen so that there will be a straight run of several hundred feet before an open four-way branch is encountered. By closing valves on intermediate branches, the effect of a long isolated line can be obtained. In operation, the valve on the main below the hydrant is closed, and water allowed to flow from the hydrant through the by-pass on the instrument. By quickly closing the by-pass valve, a water hammer of about fifteen pounds is created and recorded on the pressure gage. This pressure is maintained until the water-hammer pressure has reached the open branch at the end of the pipe line that is being tested and the drop in pressure has traveled back to the hydrant, the tuning fork vibrations showing the time for this double travel. By dividing twice the distance along the main to the open branch by the time, the rate of travel for the particular pipe is determined. This has been found to be approximately 4 200 ft. per second for 6-in. pipe and decreasing to about 3 600 ft. for 12-in. pipe. If there is any leak in the main, or in a service near the main, the water-hammer pressure is materially reduced by said leak and the chart shows separately the reduction due both to the leak and the open branch. The distance to the leak can then be determined by the time shown on the chart for the water-hammer pressure to travel to the leak and return to the pulsograph, this being multiplied by the determined rate of travel of the hammer pressure along the pipe, and divided



PULSOGRAPH IN PLACE ON HYDRANT.

by two. Several leaks have been located within limits of less than twenty feet by the use of this instrument, and the results from its further use should be interesting, as a decided saving in cost of locating leaks is anticipated.

TEMPORARY SUPPLY FROM TEN MILE RIVER.

Mention has been made of the recommendation to develop an additional temporary source of supply to meet the threatened danger of water shortage in the Croton Valley. The source selected was the Ten Mile River, a branch of the Housatonic. Surveys were made, and plans, specifications, and contract prepared for the utilization of this supply, at an estimated cost for construction of about $1 200 000, and for operation and maintenance, $183 000 annually. By October, 1911, the heavy rains and resultant run-off, together with the reduced consumption, had relieved the situation sufficiently to make it practicable to stop further work on this project, and no money was actually expended for an additional supply other than in connection with the surveys, preparation of plans, etc.

METHOD OF DETERMINING MINIMUM STORAGE REQUIRED IN CROTON VALLEY.

An interesting phase of the determination of the need for an additional supply was the fixing of the reasonable safe limit of depletion of storage on January 1 of any year. The Rippl, or mass curve method, is usually adopted in determining the safe maximum draft from any watershed. The run-off from the watershed is plotted for the entire period covered by the records, and a line is drawn representing the maximum draft on the assumption that all water stored in reservoirs would be used during the drought period, if such period were to recur. On this assumption it would be necessary that the run-off become equal to or greater than the draft on the day following the withdrawal of the last of the stored water from the reservoirs, and that the run-off would be sufficient thereafter to eventually refill the reservoirs.

While, theoretically, an engineer might assume such a rate of draft, the operating engineer responsible to nearly three million people for maintaining a continuous supply from sources depend-

ent entirely, at times, upon stored water, would be foolhardy if he allowed the storage to be depleted to such an extent. The rule adopted for New York was that the storage should not go below an amount which, added to the lowest run-off recorded for a year, would equal the anticipated consumption for such year.

The lowest recorded run-off of the Croton watershed for a calendar year was 207 m.g.d. With the consumption reduced to 275 m.g.d., the deficiency was 68 m.g.d., or 24 820 million gallons in one year. As further reduction could at that time have been made in the consumption, if necessary, the figure of 20 000 million gallons was adopted for New York conditions in 1911.

Fig. 1 shows the mass curve of flow of the Croton River during

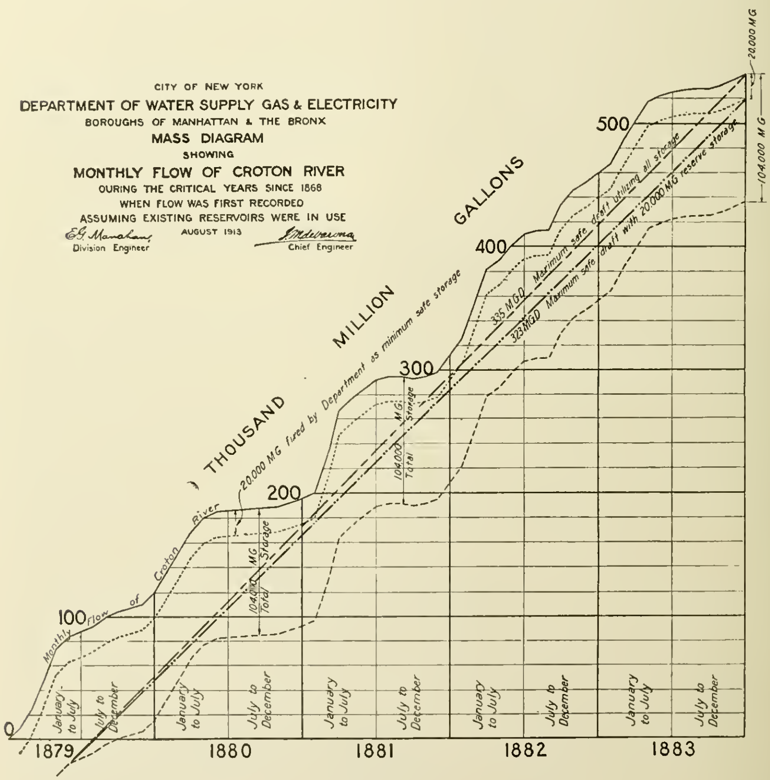


Fig. 1.

the low run-off years, and the two lines of maximum draft, one without any reserve in reservoirs and one with 20 000 million gallons reserve. The first rate is 335 m.g.d. and the second 323 m.g.d. The second is considered the safe rate of draft for New York in the light of the experience of the past three years.

Borough of Brooklyn.

While Brooklyn has for many years had little or no margin between the consumption and minimum safe supply from the system, there was no difficulty in meeting all requirements in 1911, when Manhattan and The Bronx were threatened with shortage of water. This was due mainly to a large increase in available supply from improvements in the condition of the wells, which furnish about one half of the supply, and to the reduction in consumption probably caused by general knowledge of the unusually dry season and consequent shortage of water in the Croton watershed and in many communities near New York City. The increase in consumption in the winter and spring of 1912 showed clearly that additional stations to draw from the subsurface waters of Long Island would be required unless the growth in consumption was curtailed; the consumption for the first six months being 149.1 m.g.d. as compared with a safe supply of 150 m.g.d. from the works as then developed.

Owing to the expected completion of the Catskill system in 1916 so that water could be delivered at that time to all boroughs, any new works would have a very short useful life, with consequent high cost per million gallons. On the basis of the cheapest type of station machinery and driven well system and without any allowance for conduit capacity or pumping equipment at the main station at Ridgewood, where all the water from the main watershed is pumped into the distribution reservoirs or mains, the cost delivered into the distribution system is as follows:

For water made available in 1913	$36 per mil. gal.
For water made available in 1914	42 per mil. gal.
For water made available in 1915	56 per mil. gal.

If the supply required were to be reduced so that existing sta-

TABLE 6.

Borough of Brooklyn, Average Daily Consumption, 1903 to March, 1913, Inclusive.

(Million gallons.)

Month.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
January....	107.8	116.5	123.2	121.6	134.1	141.7	133.4	142.7	151.1	156.1	122.0
February...	108.6	128.2	129.5	128.7	139.8	148.8	134.4	149.7	148.9	159.1	128.9
March.....	105.1	114.5	123.6	126.1	134.8	138.7	134.1	142.8	147.5	148.6	122.6
April......	103.0	106.6	117.8	126.3	134.0	134.4	133.5	136.3	141.0	144.0	118.6
May.......	104.8	106.5	121.5	129.5	136.6	133.8	130.3	137.2	138.4	143.8	119.3
June.......	100.7	109.0	120.3	134.3	139.0	144.7	137.2	139.1	138.5	143.1	127.6
July.......	105.2	108.4	118.3	126.3	139.1	145.7	141.3	147.6	145.5	144.2	....
August.....	102.0	110.3	114.7	130.0	135.0	143.9	142.0	143.7	138.9	136.1	....
September..	108.1	113.2	114.0	133.0	136.6	143.2	143.0	145.7	140.8	139.3	....
October....	103.7	112.7	115.3	124.7	134.6	142.6	138.5	143.6	132.6	136.5	....
November..	99.6	112.9	114.0	119.3	131.5	138.5	134.1	142.1	127.7	126.3	....
December...	108.5	119.5	119.1	125.5	132.8	132.0	136.2	146.7	133.2	126.7	....
Average..	104.7	113.1	119.2	127.1	135.6	140.6	136.5	143.1	140.3	142.0	123.2

tions could be shut down, the saving in maintenance and operation was estimated at about $24.00 per million gallons.

On the basis of the results obtained from water-waste prevention work in Manhattan and the Bronx, it was evident that such work in Brooklyn, if carried on along similar lines, would be financially advantageous. Work on detection of waste from leaks in mains and services had already been carried on along the waterfront; and owing to absence of rock and rock-filled streets in Brooklyn, there were practically no large leaks that would not show at the surface, other than along the waterfront. It was proposed, therefore, to limit the work in Brooklyn to the sending out of notices and to house-to-house inspection.

In June and July, 1912, 175 000 copies of the following notices were delivered at a cost of $1 137.50, which, together with the printing cost, made a total of $1 412.50.

IMPORTANT.

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks and toilets, faucets and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited, unless a permit is obtained from the Department.

It is hoped that you will do everything in your power to stop all unnecessary use of water. Every gallon of water that is supplied to the Borough of Brooklyn has to be pumped twice, and some of it three times, so every gallon saved means a saving to the taxpayer.

Use what you need, but do not waste it.

Yours truly,

F. T. PARSONS,

Deputy Commissioner, Borough of Brooklyn.

The consumption showed a drop of 10 m.g.d., see Table 6, which it was estimated was due to the notice. Assuming, as in

TABLE 7.

BROOKLYN,—NUMBER OF MEN EMPLOYED, PREMISES EXAMINED, AND LEAKY FIXTURES FOUND DURING HOUSE-TO-HOUSE INSPECTION, JULY, 1912, TO JUNE, 1913.

Months.	Number of Inspectors. Average per Day.	Number of Clerks for Office Work. Average per Day.	Number of Premises Inspected.	Number of Leaks Found.	Number of Premises Re-examined.	Number of Fines Imposed for Failure to Repair Fixtures.	Amount of Fines Imposed.
1912.							
August	35	9	8 764	9 333	1 022	18	$36.00
September	35	8	12 289	16 650	6 483	781	1 562.00
October	35	8	15 064	21 861	5 788	383	766.00
November	35	7	13 225	14 512	7 762	585	1 170.00
December	35	7	11 783	17 134	8 253	442	884.00
1913.							
January	36	5	6 638	11 476	6 242	761	1 522.00
February	36	5	10 757	15 713	4 482	606	1 212.00
March	36	5	10 885	14 252	5 785	282	564.00
April	36	5	14 674	14 628	4 116	643	1 286.00
May	40	5	18 668	17 440	5 528	944	1 888.00
June	..	.	.....	.....	.....	169	338.00
Total	..	.	122 747	152 999	55 461	5 614	$11 228.00

Total cost of work to June 1, 1913, $37 074.68.

TABLE 8.

SAVING OF WATER SECURED BY HOUSE-TO-HOUSE INSPECTION IN BROOKLYN, AS INDICATED BY PITOMETER GAGINGS OF CONSUMPTION.

Districts.	Character.	Daily Consumption before Inspection. Gallons.	Daily Consumption after Inspection. Gallons.	Saving. Gallons.	Saving. Per Cent.
1, 2,	Mainly business and manufacturing	23 884 000	21 547 000	2 337 000	10
3 (x),	Manufacturing and shipping	13 000 000	....	2 200 000	17
4, 5,	Mainly resident, medium-class	17 908 000	14 078 000	3 830 000	21
6, 7,	Partly residential and business	12 713 000	10 343 000	2 370 000	19
8,	Shipping and low-class tenements	9 250 000	7 750 000	1 500 000	16
9,	Shipping and low-class tenements	6 733 000	5 396 000	1 337 000	19
10,	Manufacturing and low-class dwellings	9 783 000	6 807 000	2 976 000	30
11,	Medium-class residential	9 610 000	7 110 000	2 500 000	26
12, 13 (x),	Medium-class residential	12 261 000	....	3 065 000	25
17, 23 (x),	High and medium-class residential	10 049 000	....	2 010 000	20
	Total	125 191 000	....	24 125 000	19 Average

$$\text{Saving } \frac{24\ 125\ 000}{125\ 191\ 000} = 19 \text{ per cent.}$$

Cost of pitometer gagings	$7 200.00
Cost of inspectors, clerks, etc.	29 500.00
	$36 700.00

x Indicates districts in which the saving has been estimated.

Manhattan and The Bronx, that the effect of said notice was lost in two years, the cost was $0.40 per million gallons saved.

Thirty-five inspectors were placed on the house-to-house inspection work early in August, and eight clerks were required to handle the leaks reported. The detailed results of the work of these inspectors, which was continued up to June, 1913, are given in Tables 7 and 8.

It will be seen that the reduction in consumption amounting to 24 m.g.d. effected by the inspection of buildings was much greater proportionally in Brooklyn than in Manhattan and The Bronx, the minimum reduction being 10 per cent. and the maximum 30 per cent., with an average of 19 per cent. This was probably caused by the lesser effect of the printed notices to repair leaky faucets and the elimination of the question of shortage of water in the Brooklyn campaign. In the Brooklyn work there was also a longer period elapsing between the sending out of the notices and the inspection of buildings. The net cost of this work was $26 000, and assuming, as in Manhattan, that the waste stopped would all reappear in two years' time, the cost of saving the water was $3.00 per million gallons. The amount saved per inspector employed was equal to about three quarters of a million gallons daily, which was over three times the amount per inspector in Manhattan. This was due to the work being carried on with a smaller number of inspectors, and each inspector was therefore credited with a larger saving than in the Manhattan work. If comparison is made between Manhattan and Brooklyn on the basis of inspector days, assuming that the leakage stopped would reappear in two years' time, the result is as follows:

Manhattan,	11 600 inspector days, resulting in saving
	7 800 m.g., equivalent to
	670 000 gallons per inspector day.
Brooklyn,	9 400 inspector days, resulting in saving
	8 800 m.g., equivalent to
	940 000 gallons per inspector day.

The financial returns in Brooklyn were excellent, it being practicable, with a reduced consumption, to shut down six pumping stations and to use approximately 6 m.g.d. for the Borough of Queens, eliminating thereby an equivalent amount of water pur-

chased from a private company at a cost of $65 per million gallons. It is estimated that the reduction in maintenance and operating charges due to water-waste work is about $300 000 annually.

While the results of water-waste work have been excellent, from the viewpoint of the department, one must not lose sight of the inconvenience to the consumers from house-to-house inspection and the expense involved in the repairs to defective plumbing. It is not believed that the methods adopted should be used except where very favorable results are to be expected, or else where the need for saving water is urgent. Without universal metering, however, it is necessary to adopt temporary expedients for reducing waste and conserving the water supply resources, and these expedients, as applied in New York City, have certainly been most successful.

The house-to-house inspection work was carried on under the direction of the Bureau of Water Registrar, Mr. Benjamin A. Keiley being water registrar for Manhattan, and Mr. Wm. R. McGuire, water registrar for Brooklyn. The general planning and all water measurement work was under the Bureau of Water Supply, of which Mr. I. M. deVarona is chief engineer, the writer having charge of the maintenance and operation work of said bureau.

DISCUSSION.

Mr. Edward S. Cole.* Some ten years ago the speaker had the privilege of conducting a similar investigation in New York City, which led to the introduction of the pitometer system described in the paper just read, and it is his conviction that 72 gal. per capita daily is twice as much water as the people of Manhattan and the Bronx actually use. This is based upon the well-known character of New York's population, which is overwhelmingly made up of tenement-house dwellers and small water users.

The meter records of Worcester, Mass., show that 10 or 12 gal. per capita covers the actual use of a great mass of that city's population, comprising low-cost homes of mill operatives, etc., and there are many data to prove the same thing. The actual per

* New York, N. Y.

capita requirements of Manhattan and The Bronx may be apportioned, according to the speaker's experience, as follows:

50 per cent	15 gal. daily.
20 per cent	20 gal. daily.
20 per cent	40 gal. daily.
10 per cent	100 gal. daily.

Or an average of about 30 gal. per capita — less than half the figure given by Mr. Brush in his paper as the domestic consumption of the city. From this it is reasonable to conclude that there is yet much to be done in the way of water-waste restriction in New York. Adding a fair amount for unpreventable waste, it should be possible to reduce the present per capita consumption of 72 gal. daily to 40 gal.

We should not forget that the reduction of a few gallons per capita in a great city like New York represents an enormous volume of water. For example, a saving of 30 gal. per capita for a population of 3 000 000 means 90 000 000 gal. per day, the value of which at such a time as the water shortage of 1912 in New York City is beyond calculation.

It was unfortunate that the pitometer tests of 1902 and 1903 were abruptly ended by a change of administration, for the work was only well begun. It is but reasonable to assume that, had our investigation continued, there would have been no such danger of water famine in 1911 and 1912. That the city narrowly escaped a serious water famine in those years is well understood. The rains came in the nick of time, and it would not be wise for any city to risk so grave a danger by so narrow a margin.

The lesson to be drawn from this experience is clearly that water waste in a great city cannot be stopped in a hurry. It takes time to locate underground leakage and losses, and after a system has been made comparatively tight and efficient, it will take constant supervision to maintain it so. In this country we need a system of district metering and supervision like that in use in London and other English cities. Such service is the more imperative in our larger cities, where the general introduction of meters is delayed.

Mr. W. C. Hawley.* I have only one point in which I differ from the writer, and that is I cannot agree with him that there is

* Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

no need for restricting leakage in plumbing. It is certainly not fair that "A," who puts a good class of plumbing into his building and maintains it in good shape, should be obliged to pay rates to help keep up a large plant because "B" does not put in a good class of plumbing and does not maintain it.

I have had some experience in this matter of hunting for water waste and stopping leaks, which perhaps may be of interest. In 1896, when I took charge of the plant at Atlantic City, the city was facing a water famine. In the previous August the pressure had been at times below 20 lb. per sq. in. The city was already inaugurating a general metering of all services, but there was not time to secure results in that way. We started at once a house-to-house inspection, and where leakage was found a report was made to the owner, with the threat that unless the leakage was stopped at once the premises would be metered. With the universal fear of a meter in an unmetered town we found that to be one of the most excellent arguments that we could advance: it certainly was better than a fine or threat of prosecution. The result was that in four or five months the consumption had been so reduced that we went through the following summer with an ample supply of water, and eighteen months from the time that we began we had reduced the consumption from an average of 250 to 260 gal. per day per capita to 50 or 60 gal.

At the plant with which I am now connected it became necessary to install a filter plant, and about five years ago we began work on the plant. At that time we were pumping about seven and a half million gallons per day, and there was no reason to anticipate a sudden increase in the demand. We planned therefore for a plant capable of filtering ten million gallons per day, with two extra filter tubs that could be equipped if needed, giving an immediate capacity of 12.5 m.g.d., with ultimate expansion to a capacity of 20 m.g.d. By the time the plant was completed in 1909 we found that we were pumping 10 m.g.d., and during that summer many days we were up to 11 m.g.d. We had no knowledge of where this increase was going. The following January we discovered a leak where a 4-in. cast-iron pipe had snapped square in two in the bed of an old run, and about a million gallons per day was going to waste there. Three months later

we found a very bad lead joint where a wrought-iron pipe had been leaded into the bell of a cast-iron pipe under a seventeen-foot fill, and another million gallons a day was going to waste there. I came to the conclusion that we should have some way of finding such leaks, so we invested in a pitometer and detectaphone and began a systematic hunt over our system of some one hundred and fifty miles of pipe. The results have been most satisfactory; we have reduced our pumpage materially.

I have some figures which I think would be of interest. For the year ending April 1, 1913, we pumped a total of four hundred and nine and a quarter million cubic feet in round numbers. Of this we accounted for 54 per cent. in industrial consumption; 23.1 per cent. in domestic consumption; and including sewer flush tanks, the free list to municipal buildings and schools, water used by the company in its own office buildings and for meter testing, for the boilers at the pumping stations, the stoker motors, the water used in washing at the filter plant, and that wasted in cleaning the sedimentation basins, we accounted for a total of 79.8 per cent. of the water pumped. With pump slip estimated at 2 per cent. (which of course is low, but our pumps are Riedler pumps and the amount pumped is checked day by day by Venturi meters), that gives us a total of 81.8 per cent., not making any allowance for water used for street washing, sewer flushing, or street sprinkling. And there is practically no estimating as to any of the quantities. It is interesting to note that the domestic consumption averages 24.3 gal. per person per day; our industrial consumption is unusually large, 56.7 gal. per day, so that our total consumption per capita is 105 gal. per day including the 19.1 gal. not accounted for.

It seems to me that while hunting for leaks is absolutely necessary, the prevention of leaks is equally or even more important. "An ounce of prevention is worth a pound of cure." I have found that at least two of the methods which we have adopted have proved very successful. At Atlantic City the leakage was not to any extent from the mains or from the service lines; the leaks were almost altogether in the plumbing, and the meters induced the owners to make repairs. The pressure was low, about 40 lb. normal pressure. In our plant at the present time, while we have

pressures up to 210 lb., a large part of our district is under from 100 to 170 lb. pressure, and a considerable part of our leakage is from the mains and from service lines which are lead pipe, as the soil is destructive of iron pipe. Some years ago we adopted the use of a patented coupling instead of the ordinary wiped joint. We have put in a great many of these couplings and we have not had a single case of leakage from them, except where the pipe has been disturbed. I found that fifteen or sixteen years ago a considerable number of one of the earlier forms of patented couplings were put in in one of the old plants which were purchased by our company, and of those couplings not one has given us trouble in the past eight or ten years except where it has been disturbed by some excavation. I believe that the elimination of the wiped joint has made a very material difference in the amount of leakage; and we are eliminating them just as fast as we can.

For some years past we have been using leadite for joints in our mains, and I believe that we have solved another difficulty. We have not had a leak at any of our leadite joints (except one, and that was not important), and we have not had a joint blow out. We find in addition that it has a very high resistance to the flow of electricity, and our mains are being protected from electrolysis.

I think that these are things that are equally as important as hunting for leaks, and will give results that are well worth all that they cost.

Mr. Brush. From what Mr. Hawley has just said, it seems as if I must have given a somewhat erroneous impression as to the attitude of New York City towards leakage. It is not and was not the idea in the water department of New York City that it is not important or necessary to stop existing leaks either in mains or in plumbing inside the buildings or to prevent leaks occurring in the future. As far as leaks in the mains are concerned, we have a permanent force of about fifteen men which is used for detection of leakage in the mains and services; that is, outside of the buildings.

The point that I intended to make was that with a gravity system of a capacity greater than the demand from a financial viewpoint it does not pay to go after the house leakage in a systematic way when your cost of stopping that leakage is greater than the

cost of new trunk mains, which is the only expense involved as long as your supply is greater than the demand. Even the cost for new trunk mains has been eliminated at the present time, due to the unusual large reduction in consumption. In other words, our trunk main capacity is now greater than would be really needed for the city of New York with its present consumption, as far as Manhattan and The Bronx are concerned.

At the present time metering is not a matter which is being actively discussed in New York City, because the authorities are not in favor of it; and it is doubtful whether to-day it is financially advisable. But as far as stopping leaks in the system itself is concerned, that is, in the mains and in the services outside of the houses, we believe that as a matter of efficient administration we ought to take the steps necessary to eliminate such leakage. And our experience has been that that leakage comes in the rock-filled streets.

I had charge of the removal of about thirty miles of mains in the borough of Brooklyn, where we replaced the old mains with new ones. Those mains were laid with lead joints and I think that twenty-five joints in the thirty miles would cover those that leaked. None of the joints leaked so as more than to drip, or at most to run a stream which was less than the size of a pencil. Of course a good many places do not have as good joints as Brooklyn, but the above was the experience with mains laid in Brooklyn back in '58 and '59 and removed in the period beginning with 1902.

As far as stopping leaks in the houses is concerned, we believe that in New York it should only be taken up where the financial returns are at the present time considerably greater than the cost of such work, because it is objected to by the majority of the people and is not necessary on the question of a sufficiency of the supply. We certainly believe thoroughly in going after leaks outside of the buildings, and also in going after leaks in the buildings where it is financially advisable to do so.

As I previously said, metering to-day is not a really practical question for discussion in New York; but the time will come in the not very distant future when the general metering of services will be a very important question and one that will then undoubtedly be taken up actively.

Mr. John C. Whitney. I would like to ask Mr. Brush whether he does not consider it very likely that there would be an increase in the waste of water from leaks where new systems are installed in the large buildings in New York City.

Mr. Brush. We do not anticipate any large increase in the number of leaks from that cause. We do anticipate a considerable increase in the amount of water lost through leakage, and it has been the practice in the borough of Brooklyn since 1905 to reduce that loss by a reduction in pressure during the night hours. That is, we keep the pressure during the evening and midnight and early morning hours down to, and slightly below, the pressure during the day time, by controlling the flow at the reservoir. That can be done in a large city with perfect safety, because the draft for fire purposes is small unless the fire becomes a large one, in which case the gates are open at the second alarm. There has been no difficulty in the last eight years of controlling the system that way.

There will certainly be a material increase in the amount of water lost in New York City with increased pressure, and there will be an increased pressure with the introduction of Catskill water. We have pressures as low as 20 lb. covering large areas, and such a pressure is of course unreasonable. Every city in the United States should have a pressure that will carry water to the upper floor of buildings that can be normally economically constructed in the district in question. In other words, we should supply New York City with pressure that would certainly carry water to the top of a building six to eight stories in height, which is the normal height of buildings erected on New York City land.

The question of stopping the leakage in the buildings in New York City is a different problem from that which the majority of cities have to face, due to the large amount of water that is introduced into New York City whenever any new works are constructed. When we consider that it will be eight or ten years before the question of adequate supply will come up, the problem is presented in a different light from that in which it is usually presented. The amount of money involved in stopping leakage is not one of thousands, but it runs up into hundreds of thousands.

I agree with Mr. Cole that our per capita consumption is far beyond what is necessary, but just how far beyond I am not in a position to state. In the next five years most of us will be in a much better position to settle that question in New York City and other cities than we are to-day, because every year adds to our knowledge of what is the proper per capita consumption. In New York an average consumption of around 30 gal. per person is about what is necessary for the ordinary domestic uses in families living in moderate circumstances. Of course when you get into tenements you come down to a much smaller per capita consumption, and there it might run down as low as 15 or 20 gal.

Mr. Beekman C. Little. Mr. President, I should like to ask Mr. Brush if he included in his house-to-house inspection those houses and buildings that were metered. And if so, I wonder if he made any computation of what percentage of the total leakage was found in the houses and buildings that were metered.

Mr. Brush. We did not include the metered premises except by sending printed notices to such premises. We assumed that there was leakage on metered services, but we concluded that with a greater number of unmetered premises than we could inspect we would confine our attention to them. We did not therefore inspect the metered premises.

Mr. Edward D. Eldredge. Mr. President, I would like to ask Mr. Brush if he would consider it advisable for the purpose of preventing leaks that services laid on private land as well as on the public highway should be under the control or supervision of the water department.

Mr. Brush. My personal opinion is that they should be, and furthermore that they should be installed by the department. We have our inspectors who cover the services up to the building; inside the building the department has nothing to do with the plumbing, but under our laws we are not permitted to install services. We install the taps, as they are put in entirely by the city tappers; but we have no control, other than inspection control, over the services to the building. I think that the city should have better control of the plumbing fixtures in the building. That question covers a big field and better plumbing will only come as the property owners realize that it pays to put in good plumbing

rather than to allow speculative builders to put in cheap plumbing because eventually the community has to pay the bill for both defective plumbing and leakage and waste of the water supply.

Mr. John S. Ely (*by letter*).* The present systematic attempt to reduce waste in Philadelphia was begun in April, 1912, by starting a thorough house-to-house inspection for leaking fixtures. Pitometer surveys were begun in August, 1912. The work during the first year was confined almost entirely to West Philadelphia.

For convenience in house-to-house inspection, the city was divided into twelve sections, lettered A, B, C, etc., and the blocks in each section were numbered consecutively. Fifty men were employed, at $2.00 per day, with an experienced district inspector as foreman, who laid out the work for his men each morning, assigning a certain block to each man. These inspectors found a great many leaks, and the results of their inspection began to be apparent immediately in reduced pumpage.

The corps has since been weeded out and reduced to thirty, the pay increased to $2.50 per day, and the men provided with aquaphones and taught how to use them. These aquaphones are inv uable in locating leaks in underground service and yard hydrant pipes. By their use about 1 500 such leaking underground pipes have been found.

The aquaphones are also valuable in expediting the work of inspection, for the inspector, by listening on a single spigot, can tell at once whether any water is running in the house, and if there is none, can proceed to the next house, thus saving the time and the inconvenience to the householder of a complete inspection.

The men wear badges and carry cards for identification, and the following general instructions are issued to them:

1. Inspectors must wear their badges on the outside of their coats in plain sight.
2. They must at all times be polite and courteous in their manner, and must cause householders as little inconvenience as possible.
3. They must ask permission of the householder before entering private rooms or bathrooms, and avoid doing anything which might be misconstrued on the part of the householder.
4. They will not waste time over small and trivial leaks. In leaks smaller than $\frac{1}{4}$-in. stream, it is sufficient to call the tenant's

* Assistant Engineer in Charge of Water Waste Prevention in Philadelphia.

attention to them, and no written notice to repair need be made out. It is of much more importance to spend the time in finding large leaks.

5. They will in all cases carefully examine the service pipe from the street, using an aquaphone, and in cases where there seems to be a leak in the service, it shall be followed up until located and shall be reported to the foreman at the first opportunity.

6. In cases where leaks are found of $\frac{1}{4}$-in. stream or more, the regular printed notice to repair will be carefully made out and left with the tenant, the duplicate copy being kept and given later to the foreman.

7. Inspectors will spend only enough time in each house to walk rapidly through and note the condition of plumbing. Five or ten minutes should be sufficient in all cases.

8. In cases where leaks of $\frac{1}{4}$-in. or more are found in rented houses, the name and address of the owner or agent should be taken and written on the duplicate slip.

9. Inspectors shall keep steadily at work during the whole day and endeavor to find as many *large* leaks as possible. The city pays you for your time and is entitled to it.

10. As inspectors are intrusted with discretionary duties, they will be required to display good judgment on all occasions, and lapses from a high standard of conduct will be dealt with accordingly.

A second inspection of those houses where notice to repair has been left is made about one week later. If the leak is still unrepaired, at the second inspection, a "shut-off" man is sent in a few days, and, finding the leak still not repaired, he shuts off the water at the curb.

Two clerks keep the records of the inspections and lay out the work for the second inspections and "shut-off" men.

The work of this corps is best shown by a summary of the first six months of 1913, as follows:

Number of buildings inspected	113 808	
Number of buildings showing waste	20 780	(18 per cent.)
Number of buildings repaired	17 371	
Number of buildings shut off	2 121	(Many vacant)
Fixtures repaired, toilet flush tanks	12 432	
Fixtures repaired, spigots	6 663	
Fixtures repaired, yard hydrants	1 286	
Fixtures repaired, horse troughs	36	
Fixtures repaired, service and hydrant pipes	2 367	

	Cost.	Cost per Building Inspected
Labor	$7 908.21	$0.0695
Material	100.40	
Transportation	189.10	
Total	$8 197.71	$0.072

The ordinary flush tank of cheap make is responsible for a very large percentage of the total waste. It is often concealed and a good-sized flow may run constantly with very little sound.

In August, 1912, the bureau purchased six Simplex pitometer sets, including recorders. The recorders are of a recently perfected type, giving a twenty-four-hour record of the velocity of flow in red ink on a circular chart, driven by clockwork. They were first used to check the output from the various pumping stations and filter plants. They are now being used to measure the consumption in various districts of the city, a district being isolated in the usual manner by lines of closed valves and the flow into it measured on one or more large feed mains.

In addition, a number of pitometer rods were purchased for use with a U-tube in making night block surveys. For this purpose the apparatus is set up in a shelter box over a tap in the street main at some convenient point. The adjacent territory is then cut in, a block at a time, by closing the valve at one end and feeding past the pitometer. An observer notes the deflections in the U-tube and the time of each deflection. Thus, the night rate of flow into each block is obtained (the work always being done between 11 P.M. and 5 A.M.). A report of these rates is turned in the following morning and house-to-house inspectors are sent through all the blocks which show a high rate until it is satisfactorily accounted for.

In the six square miles of territory examined in this way, only two leaks have been found in the street mains, these being small joint leaks. In all other cases, the leakage has been accounted for in broken service pipes or house plumbing.

A recent improvement in the method of making these night surveys has been made in the following manner. A short section of 6-in. flange pipe has been mounted on a light covered wagon, the pipe having 3-inch hose connections at either end, and a 1-in.

ferrule or pitometer connection in the center. The U-tube is fastened up on the inside of the wagon cover. The block to be examined is shut off at each end, and fed through a fire hydrant from another hydrant on a live block, the wagon being of course stationed between the two hydrants, thus measuring any leakage there may exist in the block.

This method has the following advantages:

1. It permits quicker work because there are fewer valves to handle. The average number of blocks covered in one night is about 20 with the wagon and 15 by the old method.

2. It is cheaper and does away with the necessity of tapping the main for a pitometer connection.

3. It can much more readily be taken to any part of the city, where surveys are desired.

It has the disadvantages of being less accurate in measuring the amount of leakage, giving rates about 30 per cent. less than the old method, due probably to loss of pressure in passing through the hose. An exact value of the leakage is not, however, necessary in rapid surveys of this character.

These surveys, when followed up by a thorough and efficient corps of house-to-house inspectors, are probably the quickest method of reducing waste in any given territory. It is not necessary for the pitometer corps to stop and examine each house and service individually, but only to find the block night rate. Likewise, it is not necessary for the corps of inspectors to examine those blocks where there has been shown to be no leakage. Each corps, therefore, reduces the work of the other. If at the same time, the district in which the work is being done is isolated and the flow into it being measured by recorders, the results of the work can be readily followed. The effects of this work are soon felt in the neighborhood in which it is being done in increased pressures.

The net result of the work done so far has been to reduce the rate of consumption in West Philadelphia from 145 gal. to 125 gal. per capita per day, or about 14 per cent.

The total pumpage for the whole city in May, June, and July, 1913, averaged 301.638 m.g.d., while for the same three months in 1912 it averaged 315.9 m.g.d., a saving of $4\frac{1}{2}$ per cent., although only about one tenth of the area has yet been covered.

Mr. Clemens Herschel* (*by letter*). Nigh two thousand years ago it was written ("De Arte Poetica," 359): "Indignor, quandoque bonus dormitat Homerus" — I become indignant when the excellent Homer occasionally nods (is careless in his statements).

That represents my feelings exactly, on reading in your paper on Water Waste Prevention Work what you say at the top of p. 420.

"With a gravity supply . . . and with ample aqueduct and reservoir capacity, there is practically no difference in cost when very little water is being drawn [for use and waste] and when a full supply [and waste] is being drawn from the watersheds — . . . cost is not affected by reduction in water waste."

This is one of those insidious and dangerous half truths, amounting to heresy, that has cost the towns and cities of the United States untold millions of dollars during the past fifty years. For you will readily see — no one quicker than yourself, on having your attention called to it — that such doctrine engenders and fixes on a community and its officials habits of waste; and these in turn make necessary "extending the water works" many years before such costly procedures would otherwise have become necessary. Indeed, I know of a case where "extending the water works" was imminent, while utilizing the waste would have presumably sufficed for that city some forty or fifty years.

Mr. Brush (*by letter*). Mr. Herschel criticises the proposition that, where the water works of a community have a capacity greater than the present needs of the community, there is no difference in cost if the amount of water drawn is in excess of the needs of said community, provided the draft is within the capacity of the works and the operating and maintenance charges are not increased.

This is the condition at the present time in the boroughs of Manhattan and The Bronx; and, as stated in the paper, the "cost," or the annual expenditure for maintenance and operation, is not affected by the amount of water now drawn from the watersheds, as the draft is well within the capacity of all parts of the system. There was no intention on the part of the writer to minimize in any way the importance, as a general proposition, of

* Civil and Hydraulic Engineer, New York City.

reducing waste of water. There are periods when, due to a combination of circumstances, the cost of reducing waste is greater than the cost of permitting it to continue, and under such conditions the writer believes that the engineer who recommends postponing water-waste prevention work is performing his duty, but he would be negligent if he failed to give ample notice to the responsible officials when there was necessity for undertaking water-waste prevention work, to avoid extending the water supply system.

The closing paragraph of the section covering "Water-Waste Work in the Future" shows clearly the writer's belief that, in the future, water-waste prevention work in New York City will again become a most important and vital financial question, and is now important as far as it relates to leakage from mains and services.

DECARBONATION AS A MEANS OF REMOVING THE CORROSIVE PROPERTIES OF PUBLIC WATER SUPPLIES.*

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DISCUSSION (*continued from page 227*).

[*September 11, 1913.*]

MR. L. B. LITCH.† Free CO_2 and the corrosion of iron pipes, producing the so-called "red water plague," are closely associated. Filtered waters in general, and particularly those which have been treated with sulphate ot alumina or sulphate of iron, have been shown to be more corrosive than unfiltered waters. Extra precautions should be taken to prevent, if possible, this increase in corrosive action.

At the suggestion of Professor Whipple, experiments were conducted at the Steelton filtration plant; and as a result of these experiments new operating and controlling features were added to its regular routine. The Steelton filtration plant is best described in "The Purification of the Water Supply of Steelton," by James H. Fuertes.‡

The raw water supply of Steelton is from the Susquehanna River. Above the filtration plant this river has four tributaries. The north and west branches unite to form the main Susquehanna River at a point 60 miles above Steelton. The Juniata and Conedogwinet Creek flow into the main river at a point 16 miles above Steelton. The north branch drains the hard coal regions of Pennsylvania; the west branch, the sandstone and shale; the Juniata, limestone and red sandstone; and the Conedogwinet Creek, a limestone region. The drainage areas of these different tributaries are semi-mountainous and the streams are, therefore,

* This paper was published in JOURNAL N. E. W. W. A., Vol. 27, p. 193.

† Steelton, Pa.

‡ Trans. Am. Soc. C. E., Vol. 66, p. 135.

more or less "flashy." The chemical characteristics of the waters of these different streams, as well as their appearance, differentiate them sharply from one another.

The temporary hardness of the water from the north branch is very low; the permanent hardness very high. The color of the turbidity is black or grayish-black, but the suspended particles are partially coagulated, although the water is not clear between the flocs. The temporary and permanent hardnesses of the water from the west branch are low, the color of the turbidity is gray, and the suspended matter is so well-coagulated in very small flocs that the water is often clear enough between flocs to be filtered without the use of additional coagulant. The temporary hardness of the Juniata River and the Conedogwinet Creek are very high; the permanent hardnesses very low. The color of the turbidity of the Juniata River is red in its lower and yellow in its upper reaches. The color of the turbidity of the Conedogwinet Creek is yellow. The waters of these two last tributaries are clay bearing and the turbidities are typical of such waters.

The alkalinity of the Susquehanna River water at Steelton varies from 2 to 68 parts per million; the free CO_2 from 2 to 8 parts per million.

During ordinary stages of the river, the waters from the different tributaries do not mix in the main river but flow past Steelton in streaks so distinct that the four colors of turbidity may be noticed at one time. At such times there is very little mixing of these different waters. However, when a heavy rainfall occurs on any one drainage area, the whole river at Steelton predicts the character of the stream draining it. When the rainfall is general the characteristics of the individual tributaries appear in the Susquehanna at Steelton in a regular sequence, dependent upon the distance from Steelton to the points where the various branches empty into the main river.

Naturally the river frequently shows the effect of transition from one type of water to another. For example, there is the so-called "switch" water. This is a mixture of yellow or red water with the black water. It appears after the crest of the black water flood has passed. This "switch" water cannot be coagulated by alum alone, despite the fact that the alkalinity ranges

from 35 to 45 parts per million. This phenomenon has been observed at other points on the Susquehanna River. Soda ash is not effective to assist coagulation, but lime can be used with satisfactory results, the treated water being well coagulated and clear between the flocs. Frequently there is no reduction in the alkalinity of this water after alum has been added. The raw water after boiling is frequently acid to phenolphthalein.

Because of the varying character of the raw water described above, and also because of a very short reaction period (twenty-eight minutes) previous to passing the water to the roughing filters, it was imperative that the peculiarities of each class of water be studied in order that a satisfactory coagulant might be obtained when chemical treatment was necessary. In order to study the peculiarities of these waters, a 10-meter Kohlrausch bridge and apparatus for measuring the electro-conductivity of the water was added to the laboratory equipment. By means of this apparatus, chemical reactions, which are so slight that they cannot be measured accurately by the titration methods of ordinary chemical analysis, may be accurately recorded. Furthermore, reactions may be studied experimentally and during their whole course without removing any of the solution experimented with, thereby keeping the experimental volumes constant.

In treating the "switch" water with alum, an increase in conductivity is noted. The amount of this increase remains practically constant, thus indicating either that no aluminium hydrate is being formed, or the formation of a soluble salt. When this water was tested for free CO_2 after the addition of alum, a slight increase in the amount of CO_2 was noted, but only to the extent of about 25 per cent. of the amount called for theoretically by the addition of any given amount of alum. The corrosive action on iron of this treated water is greater than that of the untreated water, but it can be reduced greatly by the addition of lime. Lime, however, is never added in excess; its addition is controlled by the conductivity method mentioned above.

The corrosive effect of CO_2 is greater when the alkalinity is low than when it is high. Again, the increase in free CO_2 resulting from the addition of lime to a water of low alkalinity tends to arrest, or at least retard, the complete reaction between the alum

(aluminium sulphate) and the alkalinity (calcium and magnesium bicarbonates). Under this condition, it has been shown that there is an aluminium compound remaining in solution. This condition should be avoided in plants using alum as a coagulant. It is the practice at Steelton to consider CO_2 under the varying conditions of its occurrence, and to apply the proper corrective treatment for it when necessary. As a result of this treatment, the borough prides itself upon the small amount of red water trouble which has occurred.

When applying coagulant, under ordinary conditions, to any one of the typical waters described above, the residual alkalinity is never allowed to go below 10 or 12 parts per million, and when coagulating a raw water which is changing in character rapidly, lime enough to combine with the amount of CO_2 equivalent to the amount of alum added is always used, thus insuring the practical completion of the reaction in accordance with chemical theory and preventing the formation of any compound of aluminium other than the hydrate.

More study should be made of the reaction between alum and the water which is treated. Filter plant chemists and superintendents have been too much inclined to place reliance upon the theoretical reaction between alum and alkalinity given in the text-books, as explaining the reaction which takes place in practice, where the theoretical action never takes place because interfering chemicals are never absent. It is the writer's belief that the subject should be approached from the standpoint of physical chemistry, and because the reactions are taking place in extremely dilute solutions, the laws of mass action should be regarded with due consideration.

Mr. Edward D. Eldredge.* I have had an experience in Massachusetts which in some features is unique, and to which Professor Whipple's paper particularly applies. Our supply ranks with one other in having the least color, and in the scale of hardness it ranks zero, — the only one in the state of Massachusetts having that rank. The result is that during certain periods of the year, notably in the spring, there is considerable trouble from red water. The supply is obtained from a woodland

* Superintendent Onset Water Company, Onset, Mass.

pond fed by springs, and having no stream flow in or out. The watershed is entirely wooded with oaks and pines, and the soil is sandy. During the spring, when the level of the pond is rising, there seems to be present a considerable amount of carbonic acid, presumably taken from the decomposing vegetable matter on the surface of the watershed. Some seasons the amount of carbonic acid is greater than others, notably the year 1911, when in April there were three snowstorms which covered the surface like a wet sponge. The absorption of carbonic acid at that time seemed to be greater than in any other period that we have noticed. In 1912 the rainfall was normal and there was not such a noticeable amount. This last spring, 1913, the rainfall was quite excessive in April, and we noticed similar trouble with red water. As a result of Professor Whipple's paper last winter I made some experiments with calcium hydrate. I made a saturated solution of the hydrate and added it in small quantities to a sample of water in which were immersed pieces of iron and steel, to ascertain the action as a result of the addition of the hydrate. The action was very marked; a small quantity of calcium hydrate reduced the oxidation of the metal. It is my purpose, with the authority and advice of the State Board of Health, to adopt some method of introducing calcium hydrate, or some better chemical if possible, with the idea of reducing the red water plague during that particular season when the pond is receiving its new water. I presume the subject must be familiar in other localities where water is very soft.

For service pipes we have found that cement-lined gives the best results, the water having no action on the cement. With galvanized iron we have found a number of cases where the pipes had become so much corroded and filled with tubercles that they had to be removed.

Julian S. Simsohn, Esq.* I note in Mr. Whipple's paper that he states carbonic acid gas can be as quickly and efficiently removed by soda ash as by lime. My experience has been that lime is somewhat superior, because the carbonic acid combines with it and can be removed in the filters as insoluble carbonate of lime. Soda ash, on the other hand, combines with carbonic acid to form bicarbonate of soda, a soluble product, which passes through the

* With the Electrolytic Purification Company, Philadelphia, Pa.

filters and into the supply. In hot water systems the bicarbonate of soda is decomposed, liberating carbonic acid, which is then at liberty to attack the piping. These thoughts are the result of experiments on both soda ash and lime, and in practice I have found the lime treatment to stand alone in producing a water entirely free from carbonic acid and its corrosive properties.

Mr. R. S. Weston* (*by letter*). At Reading, Mass., where there is a deferrization plant, the CO_2 is removed by the addition of lime, and the writer is informed that no corrosion of the pipes has occurred since lime was used.

In ordinary aëration by spraying downwards from perforated plates or sprinklers, it does not pay to provide for a fall of more than one meter, or 40 in. To obtain a better removal of carbon dioxide without the addition of chemicals, it is essential to expose the water in a thin layer to the action of the air. The action of the air always displaces the carbon dioxide, — at first rapidly, and then slowly, until equilibrium between the carbon dioxide in the atmosphere and that in the water is established. The rough surfaces in a bed of coke, brick, paving blocks, or in superimposed bundles of wooden slats greatly accelerate the washing out of carbon dioxide by the oxygen of the air. Dr. Dunbar, of Hamburg, has shown that if a coke bed, used for iron removal, be operated intermittently, it will absorb oxygen during the periods of rest, which oxygen will replace the carbon dioxide in the water during periods of operation.

At Reading, Mass., an aërator consisting of a bed of broken stone 3 ft. thick increased the oxygen in the water from 1.18 to 5.27 parts, and decreased the carbon dioxide from 20.0 to 7.2 parts per million.

At Rumford Falls, Me., the aërator used to treat the groundwater supply consisted of fifteen trays with perforated bottoms, placed one above another and spaced about 1.5 ft. apart. This apparatus reduced the carbon dioxide from 48 to 5 parts per million. By filling only two of the fifteen trays with broken stone, the carbon dioxide was further reduced to 3 parts per million, thus showing the results of contact.

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* Consulting Sanitary Engineer, Boston, Mass.

At Middleboro the following results were obtained with a well water having a temperature of 11.6 ° cent.:

	Parts per Million	
	Dissolved Oxygen.	Carbon Dioxide
Well water,	3.3	48
Ditto, after dripping 1.5 ft. from a spray nozzle,	. .	10
Ditto, after trickling over a depth of 4.5 ft. of coke and broken stone at a rate of 75 m.g.a.d.,	10.7	5.0
Ditto, after passing through a depth of 3 ft. of coke submerged in water, in a subsiding basin,	10.3	4.5

At Cohasset, Mass., the following results were obtained with a well water having a temperature of about 10° cent.:

	Parts per Million.	
	Dissolved Oxygen.	Carbon Dioxide
Well water,	2.4	51
Ditto, after falling 3 ft. from the spray nozzle,	4.5	11
Ditto, after passing through a depth of 5 ft. of broken stone, all submerged, the rate of passage being equivalent to 75 m.g.a.d.,	5.75	29
Ditto, after falling 3 ft. from a spray nozzle and then trickling over a depth of 5 ft. of broken stone not submerged and operating at a rate of 75 m.g.a.d.,	10.5	7.7

At Brookline experiments are being conducted to determine the most efficient method of aërating the water, as follows:

System No. 1. Spraying from a nozzle from a height of 1.5 ft.

System No. 2. Spraying from a nozzle and then allowing the water to trickle over a layer of coke 2 ft. in depth at a rate of 75 m.g.a.d.

System No. 3. Like No. 2 but with a layer of coke 5 ft. in depth.

System No. 4. Like No. 2 but with a layer of coke 10 ft. in depth.

The following results are typical. The temperature of the water at the time of the experiments was 15.5° cent.

	Parts per Million.	
	Dissolved Oxygen.	Carbon Dioxide.
Wells,	2.02	24.8
Effluent, System No. 1,	8.49	8.5
,, ,, No. 2,	8.90	5.5
,, ,, No. 3,	9.55	5.2
,, ,, No. 4,	9.63	4.8

The effect of aëration in contact varies with different waters, as well as with the relative temperatures of air and water and the intimacy of the contact between the same.

In order to increase hardness of water, it is often more convenient to spray water over broken limestone or marble than to apply to it the proper amount of calcium hydrate. The writer feels certain that it is always best to decarbonize the water to the practicable limit by aëration before beginning the addition of chemicals to reduce the corrosive effect of the water.

Prof. G. C. Whipple (*by letter*). There is one phase of the decarbonation question that was not mentioned in the original paper, namely, the effect which the addition of lime has upon the bacteria in water. Dr. A. C. Houston, of London, has shown by an interesting series of experiments that when water is treated with an excess of lime, such bacteria as those which cause typhoid fever are speedily destroyed. More recently, Mr. C. P. Hoover, the chemist-in-charge of the water filtration plant at Columbus, Ohio, has performed an even more important series of experiments, which indicate that typhoid fever bacilli die within a few hours in water from which the free carbonic acid has been removed. In other words, his experiments indicate that disinfection is obtained by the use of a smaller amount of lime than Dr. Houston contemplated using. Mr. Hoover's researches are published in the *Engineering Record* of September 6, 1913. This detailed account of the experiments is worthy of careful study. His conclusions were stated as follows:

(1) When enough lime is added to water to absorb the free and half-bound carbonic acid and to precipitate the magnesium content, the bacteria of the colon and typhoid group are killed in forty-eight hours after being so treated, provided the water does not contain large quantities of organic matter.

(2) The germicidal action is effective in from five to twenty-four hours when an excess of 1.2 to 1 gr. per gallon is added beyond that needed to reduce the temporary hardness to the lowest possible figure.

(3) Intestinal organisms will not live in water containing no free or half-bound carbonic acid.

(4) Lime-softened water inoculated with typhoid organisms or with crude sewage soon becomes free from them.

(5) The action is selective in that certain harmless bacteria grow, but the disease-producing germs do not.

It seems to the writer that if Mr. Hoover's experiments can be trusted, and they seem to have been made with the greatest care, we have here a partial explanation of the enhanced safety of water during storage in natural lakes and reservoirs.

It is a fact that has been established during recent years that algæ and other aquatic plants frequently use up all of the free carbonic acid during their growth by the biological process known as photo-synthesis. They will even remove some of the half-bound carbonic acid. It would appear, therefore, that this natural decarbonation of the water tends of itself to destroy such bacteria as the germs of typhoid fever.

Thus we see that natural storage tends to disinfect water even though the storage be short, provided that algæ are growing vigorously in the water. The term "purging," which is sometimes used to describe growths of algæ in ponds, is thus seen to have a meaning that is justified.

The title of Table 10, page 220, is slightly misleading. The figures given in the table do not show directly the reduction of carbonic acid, but rather the amounts of carbonic acid left after the stated periods of exposure.

The writer desires to thank those who have contributed to the discussion, and especially Dr. Thresh for his interesting account of English conditions. Mr. Simsohn states that he prefers lime to soda ash for the purpose of decarbonation, and with this idea the writer is in accord. Mr. Litch, of Steelton, has been carrying on a very valuable series of experiments on coagulation, and it is hoped that some day he will publish these in a more extended form so that the members of this Association may have the benefit of his work.

PROCEEDINGS.

The Thirty-Second Annual Convention.

Philadelphia, Pa., September 10, 11, 12, 1913.

The Thirty-Second Annual Convention of the New England Water Works Association was held at Philadelphia, Pa., September 10, 11, and 12, 1913.

The official headquarters of the Association were at Hotel Walton, where the sessions of the Convention were held and the Associate members displayed their exhibits.

The following named members and guests were in attendance:

Honorary Member.

Mr. F. W. Shepperd. — 1.

Members.

J. M. Anderson, M. N. Baker, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, G. H. Benzenberg, C. R. Bettes, Philander Betts, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, Dexter Brackett, W. W. Brush, James Burnie, J. S. Buzby, J. M. Caird, T. J. Carmody, C. E. Chandler, E. W. Clarke, R. C. P. Coggeshall, E. S. Cole, F. L. Cole, W. R. Conard, H. R. Cooper, G. K. Crandall, A. W. Cuddeback, C. E. Davis, J. M. Diven, F. C. Dunlap, E. R. Dyer, J. H. Dunlap, E. D. Eldredge, G. R. Ellis, E. A. Fisher, A. D. Flinn, W. B. Fuller, W. E. Fuller, A. S. Glover, J. W. Graham, F. W. Green, F. H. Gregory, Patrick Gear, F. E. Hall, L. M. Hastings, E. L. Hatch, W. C. Hawley, Allen Hazen, A. B. Hill, N. S. Hill, Jr., W. C. Hopper, F. J. Hoxie, J. L. Hyde, D. D. Jackson, A. W. Jepson, G. A. Johnson, F. T. Kemble, G. G. Kennedy, Willard Kent, J. A. Kienle, F. C. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. B. Kontkovski, B. C. Little, J. B. Longley, F. H. Luce, T. J. Lynch, M. B. Litch, Daniel McDonald, T. H. McKenzie, W. A. McKenzie, John Mayo, F. E. Merrill, H. A. Miller, E. E. Minor, F. F. Moore, J. W. Moran, J. A. Newlands, F. L. Northrop, E. L. Nuebling, A. E. Pickup, W. D. Pollard, J. C. Rickards, W. H. C. Ramsey, J. F. Reagan, Jr., A. A. Reimer, P. R. Sanders, H. W. Sanderson, G. H. Shaw, J. E. Sheldon, R. W. Sherman, M. A. Sinclair, J. Waldo Smith, W. E. Spear, J. F. Sprenkel, G. A. Stacy, G. T. Staples, W. F. Sullivan, Russell Suter, R. J. Thomas, J. L. Tighe, J. A. Tilden, J. C. Trautwine, Jr., C. H. Tuttle, J. H. Walsh, F. P. Washburn, F. J. Wise, G. C. Whipple, J. C. Whitney, Logarus White, F. E. Winsor, I. S. Wood, Walter Wood, Timothy Woodruff. — 115.

ASSOCIATES.

American Bitumastic Enamels Company, by L. Stuart, L. B Darling, G. J. Hermiston, J. Gibson, S. R. Rickards, and Harry Myers; Thomas D. Bausher; James Boyd & Bro., Inc., by Lewis Libengood; Buffalo Meter Company, by W. J. Chellew and R. L. Cook; Builders Iron Foundry, by N. L. Sammis; Central Foundry Company, by R. W. Conrow, K. G. Martin, H. J. Hoeltze, and W. H. Feltt; Chapman Valve Manufacturing Company, by J. T. Mulgrew; Eddy Valve Company, by F. S. Robinson; Electro Bleaching Gas Company, by E. D. Kingsley; *Engineering Record*, by A. E. Warner, R. K. Tomlin, Jr., and I. S. Holbrook; Gamon Meter Company, by C. A. Vaughan; Glauber Brass Manufacturing Company, by J. Bernstein; Joseph Dixon Crucible Company, by R. R. Belville; Hays Manufacturing Company, by C. E. Mueller; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, W. C. Sherwood, W. T. Kershaw, O. P. Hanks, and. B. D. Hutley; Lead Lined Iron Pipe Company, by J. W. McCormack and T. E. Dwyer; The Leadite Company, by J. G. McKay, George McKay, Jr., and J. P. McKay; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell, F. B. Mueller, and O. B. Mueller; National Meter Company, by E. E. Cooke, J. G. Lufkin, and W. P. Oliver; National Tube Company, by H. T. Miller; National Water Main Cleaning Company, by A. J. Yeager, B. B. Hodgman, and Clinton Inglee; Neptune Meter Company, by R. D. Wertz and T. D. Faulks; New York Continental Jewell Filtration Company, by E. K. Sorenson; Pittsburgh Meter Company, by V. E. Arnold, T. C. Clifford, and J. W. Turner; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; S. E. T. Valve and Hydrant Company, by C. L. Lincoln and E. I. Corcannon; Simplex Valve and Meter Company, by W. T. Harveson, E. R. Glenn, C. C. Behney, A. C. Fisher, and M. M. Borden; A. P. Smith Manufacturing Company, by D. F. O'Brien, F. L. Northrop, T. F. Halpin, and A. C. Nieman; Standard Cast Iron Pipe and Foundry Company, by W. F. Dodds, W. C. Hammond, and W. F. Woodburn; Thomson Meter Company, by E. M. Shedd, W. S. Cetti, S. D. Higley, and J. L. Atwell; Union Water Meter Company, by L. P. Anderson and Edward Otis; Water Works Equipment Company, by W. H. Van Winkle, W. H. Van Winkle, Jr., and E. T. Scott; R. D. Wood & Co., by C. R. Wood, A. T. Prentice, H. M. Simons, and Walter Wood; Henry R. Worthington, by J. A. Post, Samuel Harrison, T. C. McBride, P. B. Fenlon, J. E. Torbush, C. H. Morse, C. F. Carver. — 91.

GUESTS.

Mrs. James Burnie, Miss Helen M. Burnie, Biddeford, Me.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. George T. Staples, Dedham, Mass.; Mrs. George A. Caldwell, W. J. Rose, W. R. Taylor, Mrs. Albert S. Glover, Mrs. Dexter Brackett, Miss Joan M. Ham, Boston, Mass.; Mrs. J. L. Hyde, Miss Helen Sanderson, Westfield, Mass.; Mrs. John Mayo, Bridgewater, Mass.;

Neddie Eldredge, Onset, Mass.; Mrs. George A. Stacy, Marlboro, Mass.; Mrs. Arthur E. Blackmer, Plymouth, Mass.; Mrs. Frank E. Merrill, Somerville, Mass.; Mrs. L. M. Hastings, Cambridge, Mass.; Mrs. Thomas J. Carmody, Joseph Lynch, Holyoke, Mass.; John E. Sullivan, Lowell, Mass.; Mrs. Irving S. Wood and D. K. Bartlett, Providence, R. I.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. George K. Crandall, New London, Conn.; Mrs. Charles E. Chandler, Norwich, Conn.; Mr. H. R. Cooper, Thompsonville, Conn.; Mrs. T. H. McKenzie, Hartford, Conn.; S. W. Hume, F. M. Griswold, James H. Van Burke, Mrs. John H. Gregory, Mrs. F. W. Shepperd, Fred Shepperd, Nathan C. Rockwood, Mrs. W. W. Brush, Fred W. Schultz, Mrs. I. S. Holbrook, Dr. George Ornstein, M. F. Tiernan, New York City; Mrs. Frank E. Winsor, White Plains, N. Y.; Charles H. White, New York City; Mrs. Fred F. Moore, Hawthorne, N. Y.; Mrs. James M. Caird, Mrs. Fred S. Bates, Troy, N. Y.; D. C. Randall, Tupper Lake, N. Y.; Miss Celia Ryan, Ausable Forks, N. Y.; D. N. Durland, Far Rockaway, N. Y.; D. A. DeCrow, Buffalo, N. Y.; Mrs. T. F. Halpin, Newark, N. J.; Alvin Bugbee, Charles H. Speck, Wm. J. Stewart, Trenton, N. J.; Mrs. F. W. Green, Little Falls, N. J.; C. D. Mathews, Camden, N. J.; B. F. Souder, Atlantic City, N. J.; Henry Ryan, Bridgeton, N. J.; J. W. Griffin, Jersey City, N. J.; Mrs. F. C. Kimball, Summit, N. J.; Mrs. G. G. Kennedy, Harrisburg, Pa.; J. Benbaker, Jenkintown, Pa.; George H. Wobensmith, C. A. Vance, Joseph Thompson, Julian S. Lincoln, Miss Longstreth, N. M. Akimoff, Mrs. George E. Nichols, Mrs. John C. Trautwine, Jr., H. W. Benjamin, C. P. Landreth, Mrs. G. M. Costello, George F. Noer, George M. Costello, Graham Starr, F. C. Viguerie, W. Whitby, Arthur C. Merrill, H. S. Purdy, Joseph Fenerty, Francis D. West, John Moody, Edward O'Brien, J. C. McHugh, C. N. Kaprie, Philadelphia, Pa.; M. K. Smith, Charles T. Martin, Wilmington, Del.; G. W. Young, Canton, N. C.; Miss May S. Pollard, J. F. Pollard, Pottsville, Pa.; Mrs. C. E. Mueller, Erie, Pa.; Mrs. M. B. Litch, Steelton, Pa.; Walter L. Watson, North Catasauqua, Pa.; Edward Elbert, Reading, Pa.; J. Archibald, Newtown, L. I.; Mrs. J. H. Dunlap, Iowa City, Ia. — 96.

Wednesday, September 10, Morning Session.

The convention was called to order at 10.30 A.M. by J. Waldo Smith, the President, who said:

When Director Cooke sent us a most cordial invitation to meet in convention in this city, we all expressed not only our willingness but our anxiety to come, for the fame of the chief executive of this city had gone abroad. We had heard that he was a man of great courage and great independence; that he was trying to give this city a practical business administration; and that to this he was appointing men to the principal positions in the city for merit

and fitness and not by reason of any political service, and that after these men had been appointed they were left to make good, — they were not trammeled in making their appointments or choosing their associates. This is a most unusual thing in a great city like Philadelphia.

It is with great pleasure that I introduce to you Mayor Blankenburg, of Philadelphia.

HON. RUDOLPH BLANKENBURG. *Mr. Chairman and Members of the New England Water Works Association,* — I appreciate the very kindly introduction at the hands of your chairman. I am glad that the fame of this administration has reached outside of Philadelphia, because there are quite a number of people in Philadelphia who have not as yet heard of it. Perhaps it is because they don't want to hear. There are unfortunately too many people in this world who won't learn and who won't believe facts; but the facts are here.

As your presiding officer has said, it has been my aim to give Philadelphia a thorough business administration. That is the one thing needed in every municipality over our broad land. We must exclude politics in every way if we want to achieve and accomplish that kind of municipal government which will be of the greatest benefit to the masses of the people. This has been my aim, and I am glad to be able to look at two representatives of this administration who were appointed by me and through me and who are making good in every way. Let me assure you, gentlemen, that I have never yet asked a man's politics or his religion when I appointed him to office or was instrumental in having the appointment go to him, and I never shall. Efficiency is the watchword that has been the ground work of this administration.

I speak to you feelingly, gentlemen, because you are the oldest association in this country, — the New England Water Works Association. You have done a great deal of good, and you are not confined to-day, as I understand, to New England, but you embrace many parts of this country.

It is well that New England should come to Philadelphia, for in New England, in the city of Boston, — next to Philadelphia, of course, — we find more of the old spirit that was imbued and

that was implanted in our people during the War of Independence than in any other part of the country. People living in the far West cannot help it, because that was not part of our country then. But we will give you a Roland for your Oliver every time. You point with pride to Bunker Hill; we take you to Independence Hall. But we do not want to speak of this, because we are all one people, we are all united in one purpose, — to show to the world that the republican form of government can be established and maintained, and that it is not a failure.

Now, gentlemen, as mayor of this city I extend to you a most hearty welcome. We are really being favored, for the New England Water Works Association is with us to-day and the American Water Works Association will be with us next spring. There will be plenty of water to discuss. I don't know how it is with you, but sometimes here in Philadelphia we find a stick in the water. But we don't find any unfiltered water, any raw water. We are not giving you a raw welcome; we are giving you a welcome that is thoroughly filtered and clean, at least as far as the water is concerned.

I am not going to detain you by a lengthy speech. I believe Philadelphia is the first city in which water works were established, — by Benjamin Franklin. We often brag about Benjamin Franklin, and then the retort comes to us, " Oh, yes; but we gave him to you from New England." He wasn't a real Philadelphian, he was only imported — as I was myself. But Philadelphia had the first water works, and those old, old water works are still visible.

Make yourselves comfortable while you are in our city. The freedom of Philadelphia is extended to you most heartily. Have a good time, and I hope that you will remember your visit to Philadelphia in the future with the greatest of pleasure.

The President. On behalf of the New England Water Works Association I thank you most heartily, Mr. Mayor, for this very cordial reception. I am sure that with all you have provided for us, and because of the historic interest of the city, our stay here will be most pleasant, agreeable, and instructive. And I hope that this meeting will prove of profit to you and your great city.

We have here with us Mayor Blankenburg's right-hand man,

Director Cooke, who presides, as I understand, over most of the departments of this city. We feel very cordial towards Mr. Cooke, because he saw fit to choose as his principal assistant in the water department a son of New England and a member of this Association. We would be very glad if Mr. Cooke would say a word to us.

Mr. Morris L. Cooke.* *Mr. Chairman and Gentlemen,* — It is a great pleasure to say just a word. I am going to confine it simply to thanking the men in this room, as representing the engineering profession in this country, for the truly remarkable support that this administration has had at the hands of that profession. From every branch of engineering word has come to us, "We are at your service, and we are on call." Starting in as we did in many departments of the city administration without the most adequate engineering advice, it has been necessary on a great many occasions to go to the leading men in your profession, and in the engineering profession both in your branch and others. In every instance that appeal has not only not been in vain, but we have had a response and a character of assistance that would have made the engineering department of any administration a success.

As far as your stay here is concerned, I want to add my word to that of his honor the mayor in trusting that you will have a good time, and in begging that you will command my office if there is any way in which we can be of assistance.

The Secretary read the following names of applicants for membership, all of whom had been properly endorsed and approved by the Executive Committee:

Active: Weston E. Fuller, New York City; William John Turnbull, State Farm, Mass.; E. W. Sylvester, City Hall, Poughkeepsie, N. Y.; M. B. Litch, Steelton, Pa.; N. W. Akimoff, Philadelphia, Pa.; Eugene B. Kontkovski, St. Petersburg, Russia; Lazarus White, New York City; Wilbur Thomas Wilson, New York City; Frederick E. Tupper, City Hall, Quincy, Mass.; D. C. Shull, Apollo, Pa.; Walter P. Schwabe, Windsor Locks, Conn.; Jacob S. Langthorn, New York City; Arthur N. Burnie, Biddeford, Me.

* Director of the Department of Public Works, Philadelphia.

Associates: James Boyd & Bro., Inc., Philadelphia, Pa.; Buffalo Meter Company, Buffalo, N. Y.; Simplex Valve and Meter Company, Philadelphia, Pa.; American Bitumastic Enamels Company, New York City; The Leadite Company, Philadelphia, Pa.; Joseph Dixon Crucible Company, Jersey City, N. J.

On motion the Secretary was empowered to cast the ballot of the Association in favor of the candidates, and, he having done so, they were declared by the President duly elected members of the Association.

Mr. George A. King moved that the President be empowered to appoint a committee of five to nominate officers for 1914. The motion was adopted. The President subsequently appointed the following committee: Robert C. P. Coggeshall, chairman; George A. Stacy, Edwin C. Brooks, George C. Whipple, Charles W. Sherman.

The first paper on the program was on "Notes on Reduction of Waste of Water in New York City," by William W. Brush, deputy chief engineer, Department of Water Supply, Gas, and Electricity, New York City. The paper was discussed by Mr. Edward S. Cole, 220 Broadway, New York City; Mr. W. C. Hawley, chief engineer and general superintendent Pennsylvania Water Company, Wilkinsburg, Pa.; Mr. John S. Ely, assistant engineer in the Bureau of Water, Philadelphia; Mr. John C. Whitney, water commissioner, Newton, Mass.; Mr. Beekman C. Little, superintendent water works, Rochester, N. Y.; and Mr. Edward D. Eldredge, superintendent Onset Water Company, Onset, Mass.

Mr. A. W. Cuddeback, engineer and superintendent, Passaic Water Company, Paterson, N. J., read a paper entitled "Effect of the Condition of Meters on Revenue." This paper was discussed by Mr. Theodore H. McKenzie, secretary and treasurer Terryville (Conn.) Water Company, Southington, Conn.; Mr. John C. Whitney; Mr. William F. Sullivan, engineer and superintendent Pennichuck Water Works, Nashua, N. H.; Prof. Philander Betts, chief engineer Public Utilities Commission, State of New Jersey, Newark, N. J.; Mr. George A. King, superintendent water works, Taunton, Mass.; Mr. W. C. Hawley; Mr. Francis T. Kemble, secretary New Rochelle Water Company, New Rochelle, N. Y.; and Mr. John C. Trautwine, Jr., of Philadelphia.

Afternoon Session.

The President. The chairman of the committee on arrangements, Mr. Davis, has an announcement to make about the excursion to-morrow afternoon.

Mr. Davis announced that an excursion had been arranged by sight-seeing automobiles through portions of Fairmount Park, including stops at Queen Lane Pumping Station, Queen Lane Filters, and one of the high pressure fire stations, where a fire company would be called out and a demonstration given.

The first business of the afternoon was an illustrated paper by Mr. Hiram A. Miller, consulting engineer, of Boston, Mass., on "The Additional Water Supply for the City of Pittsfield, Mass."

The President. There are two matters laid over from the March meeting for discussion at this meeting. The first is the report of the Committee on Water Consumption and Statistics Relating Thereto, which was presented at the March meeting of the Association by Mr. Leonard Metcalf, the chairman. An opportunity is now afforded for further discussion of this report of the special committee on that subject. I would suggest that members who are interested in this subject will read carefully the very excellent report which was presented by this committee, and be prepared to take up the discussion of it at a winter meeting. This Association has always done very high-grade work in the reports of its committees, and it is desirable that this should be reviewed in the most thorough manner before it is finally adopted.

The report of the committee on "Low Yields of Catchment Areas in New England, and, at Their Discretion, Outside of New New England," comes up at this time. The chairman of that committee is not here, but I think some of the members of that committee are present. Discussion or remarks are invited. If there is no objection this report will also be laid over to a winter meeting.

Does any person present wish to suggest any further business to bring to the attention of this meeting at this time? There being no response a recess will be taken until eight o'clock this evening, when further papers will be presented.

Evening Session.

The President. In order that we may have a better understanding of the Philadelphia water works which we are to visit on Friday, Mr. Carleton E. Davis, the chairman of the committee on arrangements, and the chief engineer of the Bureau of Water of Philadelphia, will give an outline description of the Philadelphia water-works.

Mr. Davis then gave an illustrated talk on the Philadelphia water-works system.

Next came a paper by Mr. Francis D. West, chemist in charge, Torresdale Laboratory, on the "Torresdale Filter Plant Methods and Results from 1907 to Date," illustrated. The paper was discussed by Prof. George C. Whipple, of Harvard University; Mr. John H. Gregory, consulting engineer, New York City; Mr. Trautwine; Mr. Joseph S. V. Siddons, superintendent Torresdale Filters; and Mr. John A. Kienle, sanitary engineer, Electric Bleaching Gas Company, New York City.

A paper followed, on "Mortality Rates of Philadelphia in Relation to the Water Supply," by John A. Vogleson, chief of the Philadelphia Bureau of Health. As Mr. Vogleson was absent from the city his paper was read by Dr. Joseph S. Neff, of Philadelphia, Director of Public Health. At the conclusion of the paper it was discussed by Mr. John A. Kienle; Mr. Edgar M. Hoopes, Jr., chief engineer of the Water Department, Wilmington, Del.; Mr. Richard Winslow Sherman, chief engineer Conservation Commission, Albany, N. Y.; and Mr. W. C. Hawley.

Thursday, September 11, Morning Session.

The day's proceedings began with the reading of a paper by Mr. F. J. Hoxie, engineer and special inspector, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., on "Methods of Locating Leaks in Water Mains." This was discussed by Mr. Allen Hazen, civil engineer, New York City; Mr. R. C. P. Coggeshall, superintendent water works, New Bedford, Mass.; Mr. Dexter Brackett, chief engineer Metropolitan Water Works, Boston, Mass.; Mr. George A. Stacy, superintendent water works, Marlboro, Mass.; Mr. W. C. Hawley; and Mr.

Patrick Gear, superintendent Holyoke Water Department, Holyoke, Mass.

A paper entitled "Loss of Head in Bends" was read by Mr. Weston E. Fuller, consulting engineer, New York City, and was discussed by Mr. Francis T. Kemble, Mr. Allen Hazen, and Mr. Richard Winslow Sherman.

Then came discussion of paper by Prof. George C. Whipple, on "Decarbonation of Water," which was presented at the March meeting of the Association. The President said that this was a subject that ought to appeal particularly to the men interested in filtration, and those troubled with the red water plague, and he called upon Mr. Whipple to open the discussion by saying more about his paper. It was also discussed by Mr. M. B. Litch, Steelton, Pa.; Mr. Edward D. Eldredge; and Mr. Julian S. Simsohn, electro-chemist, Electrolytic Purification Company, Philadelphia.

The President called for progress report from the committee on "Standard Specifications for Cast-Iron Pipe," Mr. F. A. McInnes chairman.

The President. I think Mr. King has a report to make.

Mr. King. The committee has done some work, and can only report progress at this time. I have a letter here from Mr. McInnes, which I will read.

Boston, Mass., August 27, 1913.

Willard Kent, *Secretary*,
New England Water Works Association,
Narragansett Pier, R. I.

Dear Sir, — The committee on "Standard Form of Specifications for Cast-Iron Water Pipe and Special Castings" is not ready to report at the annual convention about to be held in Philadelphia. It is necessary to "Make haste slowly" in this matter, so many different interests being involved.

Yours very truly,
F. A. McInnes, *Vice-President.*

The President. There is also a progress report due on "Standard Specifications for Hydrants," Mr. H. A. Lacount, chairman. Is there any report on this subject? Does any one desire to say anything on the subject of "Standard Specifications for Hy-

drants"? There being no response I will call on Mr. Griswold to tell us about the standard hose couplings.

Mr. F. M. Griswold, general inspector, the Home Insurance Company, New York, then addressed the meeting in regard to the Standard hose coupling.

Mr. W. F. Woodburn presented the following report of the Committee on Exhibits.

PHILADELPHIA, September 11, 1913.

Mr. J. WALDO SMITH, *President New England Water Works Association:*

Dear Sir, — I take pleasure in submitting the report of the Committee on Exhibits.

The following Associate members exhibited:

H. Mueller Manufacturing Company, Decatur, Ill., brass goods, tapping machines, water meter tester, large pipe cutter, and other tools and appliances; A. P. Smith Manufacturing Company, East Orange, N. J., large and small tapping machines, fire hydrants, gates, brass goods and appliances; Hays Manufacturing Company, brass goods, tapping machines, curb boxes, etc.; Chapman Valve Manufacturing Company, Boston, Mass., brass and iron body gate valves, Anderson couplings, and fire hydrants; S. E. T. Valve and Hydrant Company, New York, gate and curb boxes; Lead Lined Iron Pipe Company, Wakefield, Mass., lead and tin lined pipe; Water Works Equipment Company, New York, tapping machines, automatic calking and tamping tools, etc.; National Tube Company, Pittsburg, Pa., black and galvanized pipe and special lead joints; Central Foundry Company, New York, Universal pipe; Ross Valve Manufacturing Company, high pressure fire hydrants, regulator valves, etc.; Simplex Valve and Meter Company, Philadelphia, Pa., meters and valves; Builders Iron Foundry Company, Providence, R. I., meters; Electro Bleaching Gas Company, New York, N. Y., water purifying apparatus; National Water Main Cleaning Company, New York, samples of filled and cleaned water mains; Standard Cast Iron Pipe and Foundry Company, Bristol, Pa., and Malden, Mass., cast iron pipe; American Bitumastic Enamel Company, Philadelphia and New York, preservative enamel; Joseph Dixon Crucible Company, Jersey City, N. J., graphite and preservative paint; The Leadite Company, Philadelphia, Pa., leadite and leadite gasolene furnace; T. D. Bausher, Reading, Pa., lead melting furnace and fuel; James Boyd & Bro., Inc., Philadelphia, Pa., pump valves and appliances; Hersey Manufacturing Company, South Boston, Mass., water meters; Neptune Meter Company, New York, N. Y., water meters; Henry R. Worthington, Boston, Mass., New York and Philadelphia, water meters; National Meter Company, New York and Boston, Mass., water meters; Thomson Meter Company, Brooklyn, N. Y., water meters; Union Water Meter Company, Worcester, Mass., water meters; Gamon Meter Company, Newark, N. J., water meters; Pittsburg Meter Company, East Pittsburg,

Pa., and New York, water meters; Buffalo Meter Company, Buffalo, N. Y., water meters; *Fire and Water Engineering; Engineering News; Engineering Record; American City.*

Submitted by

Wm. F. Woodburn, *Chairman,*
Frank L. Northrup,
Thomas McBride,

Committee on Exhibits.

The President. Is there any further business to be brought to the attention of this meeting at this time?

Prof. George C. Whipple. *Mr. President,* — Last evening in the discussion of Mr. West's paper* I made a suggestion which I would like to place before the Association at this time in a more formal way. It is that a committee be appointed to consider and report upon the statistics of filter operation. It seems to me that there is need for some work to be done along this line, for when one studies and looks over the reports that describe the operation of filters in various parts of the country, he finds that they are in many ways very unsatisfactory. They are not uniform, and it is difficult to compare the results of one filter with those of another. There are many changes that need to be made in our methods of report. It seems to me that the whole subject is one that is worthy of being considered by this Association, and I therefore make the motion, Mr. President, that a committee of five be appointed to consider the subject of the statistics of filter operation and report at the next convention of the Association.

Mr. Frank W. Green.† *Mr. President,* — I would like to second that motion. In my position as superintendent of a filtration works, I have frequently noticed the need of such a report. It would be a very good thing if we could get some line on the subject, and have the reports from the many plants throughout the country conform, as nearly as is possible, to a given standard. As it is now, nearly every filter has its own form of report, some of them being rather too full and some are not explicit enough. The form of the reports would necessarily have to be changed from time to time. Only a few years ago very little attention was paid to the sterilization of water that had been

* See page 394.
† Superintendent of Filtration, Montclair Water Company, Little Falls, N. J.

filtered; the question of the pollution by bacteria was almost a sealed book at that time, while at present daily analyses of their number are made at many plants, and we can even detect whether the typhoid bacilli are present or not. The subject of free carbonic acid and the other properties that cause "red water," — they have assumed a very important position in some of our eastern supplies. We can, therefore, see how important it is to have a standard form of report, not only to enable us to secure data relative to the operation of the various plants as conducted in the past, but to enable us to more readily secure additional information along such lines as may develop in the future.

Mr. George A. Stacy. I want to know if that simply includes water filtration. I think it should go further and include sewage filtration, so that the comparison could be more easily made if it is desirable. It seems to me that sewage filtration is coming to the front very fast in this country, and the standardization of reports and statistics would enable them to be compared one with the other.

Mr. Allen Hazen. I think it is certainly as important in the case of sewage as it is with water. But this is a water-works organization, and it should be our endeavor to keep the sewage and the water as far apart as we can.

Mr. Stacy. I find that we would like to keep them as far apart as we can, but in spite of everything they are coming together and we have got to butt up against the whole question.

The motion was carried.

The President subsequently appointed the following committee: Prof. G. C. Whipple, Messrs. F. W. Green, E. E. Lockridge, F. D. West, and R. S. Weston.

Evening Session.

The Secretary read the following list of applications for membership.

Active: John Hoffman Dunlap, Iowa City, Ia.; F. M. Griswold, New York City; Daniel A. McCrudden, Philadelphia, Pa.; D. C. Randall, Tupper Lake, N. Y.; Robert Robertson, Beverly, Mass.; Patrick Gear, Holyoke, Mass.; Francis D. West, Philadelphia, Pa.

Associate: S. E. T. Valve and Hydrant Company, New York City.

The applications were all properly endorsed and recommended by the Executive Committee, and on motion the Secretary cast a ballot in favor of the applicants.

Mr. Walter E. Spear, department engineer, Board of Water Supply, New York City, gave an illustrated paper on "The City Tunnel and Conduits of the Catskill Aqueduct." At the conclusion of his paper Mr. Spear called upon Mr. Lazarus White, in charge of the southerly half of the tunnel as division engineer, who gave some details in connection with the work. At the request of the President, Mr. Trautwine then showed some slides illustrating water hammer, and after a vote of thinks to the committee on arrangements for the excellent entertainment which they had furnished, the Convention adjourned.

EXECUTIVE COMMITTEE.

PHILADELPHIA, PA., September 10, 1913.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Walton, at 10 A.M., Thursday, September 10, 1913.

Present, President J. Waldo Smith, and members William F. Sullivan, George A. Stacy, James L. Tighe, James W. Blackmer, Willard Kent, Lewis M. Bancroft, and George A. King.

Twenty applications for membership were received, viz.:

For members: D. C. Shull, superintendent Apollo Water Works Company, Apollo, Pa.; Walter P. Schwabe, general manager Northern Connecticut Light and Power Company, Windsor Locks, Conn.; N. W. Akimoff, hydraulic engineer, Philadelphia, Pa.; William J. Turnbull, engineer Mass. State Farm, State Farm, Mass.; Gen. Eugene B. Kontkovski, consulting engineer, General Corps of Engineers, St. Petersburg, Russia; M. B. Litch, superintendent and chemist Steelton Filtration Plant, Steelton, Pa.; Arthur N. Burnie, assistant superintendent Biddeford and Saco Water Company, Biddeford, Me.; E. W. Sylvester, superintendent public works, Poughkeepsie, N. Y.; Lazarus White, division engineer, Board of Water Supply of the City of New York; Weston E. Fuller, of firm of Hazen & Whipple, New York City; Frederick E. Tupper, commissioner public works, Quincy, Mass.; Jacob L. Langthorn, division engineer, Board of Water Supply of the City of New York; Wilbur Thomas Wilson, assistant engineer (designer) and assistant superintendent Board of Water Supply of the City of New York;

For associates: Joseph Dixon Crucible Company, Jersey City, N. J.; Simplex Valve and Meter Company, Philadelphia, Pa.; Electro Bleaching Gas Company, New York; James Boyd & Bro., Inc., Philadelphia, Pa.; American Bitumastic Enamels Company, New York City, N. Y.; Buffalo Meter Company, Buffalo, N. Y.; The Leadite Company, Philadelphia, Pa;

and the applicants were by unanimous vote recommended for admission in their respective grades.

Adjourned.

WILLARD KENT, *Secretary.*

PHILADELPHIA, PA., September 11, 1913.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Walton, at 8.30 P.M., Thursday, September 11, 1913.

Present, J. Waldo Smith, President, and members William F. Sullivan, George A. Stacy, James L. Tighe, James W. Blackmer, Willard Kent, Lewis M. Bancroft, and George A. King.

Eight applications for membership were received, namely,

For members: F. M. Griswold, general inspector, Home Insurance Company, 56 Cedar Street, New York City, N. Y.; Robert Robertson, chairman Water Commissioners, 83 Lovett Street, Beverly, Mass.; Patrick Gear, superintendent Water Department, 42 Commercial Street, Holyoke, Mass.; Francis D. West, chemist in charge Torresdale Laboratory, Philadelphia Bureau of Water, Torresdale, Pa.; Dan A. McCrudden, 5931 Pulaski Avenue, Philadelphia, Pa.; D. C. Randall, superintendent Tupper Lake Water Company, Tupper Lake, N. Y.; John Hoffman Dunlap, professor hydraulics and sanitary engineering, State University of Iowa, Iowa City, Ia.;

For associate: S. E. T. Valve and Hydrant Company, New York City, N. Y.;

and they were by unanimous vote approved for membership in their respective grades.

Adjourned.

WILLARD KENT, *Secretary.*

New England Water Works Association.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE CARE AND MAINTENANCE OF METERS AND THE EFFECT ON REVENUE.

BY A. W. CUDDEBACK, SUPERINTENDENT AND ENGINEER, PASSAIC WATER CO.

[*Read September 10, 1913.*]

With the coming of government regulation of water rates through the public utility commissions, and the basing of these rates by the commissions upon a valuation of the property, the need for careful and economical operation of water departments will be emphasized, and a careless, slipshod manner of doing business will be likely to land the water company or department in financial difficulties.

It becomes important under these conditions to conserve the water supplies already developed, and to this end the selling of water by meter will receive an impetus. The flat or annual method of charging for water has its advantages and its disadvantages, and among the chief of its disadvantges is that there is no immediate individual penalty to follow the wilful or careless waste of water, and the inevitable result is that a large percentage of the water delivered to a community under this system is, unless there is maintained an exceptionally efficient and constant inspection, wasted through leaky fixtures.

The advent of the meter as a means of measuring water delivered to the customer and to determine the amount he should pay for service in accordance with the amount delivered into his premises should check the needless waste going on under the old method; but, in order that the meter may completely accomplish this desired

result, it is necessary that it should be at all times in good condition and adjusted to the work it is to perform. In other words, it must measure accurately all of the water entering the premises, or it fails in its principal purpose of checking waste and placing the charge for water where it belongs on the user or waster, as the case may be.

It is not enough that a meter should register accurately at the time it is put into service. It should first be suitable for the service it is to perform, i. e., it must be of the proper size and type for the particular work it is to do. The determination of the type and size for the ordinary domestic service is not difficult, but in a water system of any size there are many services that require some study to determine the proper meter to secure the best results. In large factories the use of water may be so varied that no single service can be equipped with a simple meter to satisfactorily and accurately measure all of the water. The interests of the consumer and the water department are sometimes antagonistic in these cases; the consumer demands a large full flow at times, while at other times only a small flow is demanded, and in many cases a fire protection service is also expected from the same source. It is obvious that the water department cannot hope to satisfy all of these demands, and still economically and efficiently as well, measure the water through one instrument. All of these considerations show the necessity of a careful determination of the type and size of meter to be used, and necessitates the decision of a man who not only knows the conditions to be met with in each particular case, but one who knows just what results can be accomplished by the use of different types and sizes of meters.

After these preliminary questions of type and size of meter are determined, the work of the intelligent meter-man is just nicely started. No sense of false security should now be allowed to abate the activity with which he should follow up and watch the performance of the instrument that he has set to determine the money that each water user must pay for the service rendered to him.

The dishonest water user who will tamper with the meter (for there are a few of these in every community) is not the enemy to cause the most worry, although he needs attention, and the various

ways by which he can affect the registration of the meter should be known to the wide-awake meter-man. The condition of the ordinary service meter should be carefully watched, and to do this intelligently and effectively requires not only experience and a knowledge of the character of the service to which attached, but careful, continuous, and painstaking work on the part of the man responsible for the condition of the meters.

The methods by which we determine the meters to be removed for test, and keep ourselves informed as to the performance of individual meters, will be given in some detail, as we consider it of great importance, and some of the results shown justify these conclusions.

The readings of the meters are taken on loose-leaf slips, which always have on them at least a year's record of the consumption at that particular property, and on an average the record for a much longer period. On the back of this slip is noted the character of the property supplied; a record of the number of families; important fixtures, business, etc., any information that may be useful to the meter superintendent in helping him to arrive at an instant conclusion as to whether the meter is performing its work or not.

We aim to maintain not only accuracy, but a sensitiveness close enough to measure the innumerable small leaks that occur in plumbing fixtures, and to do this requires unceasing and careful study of the various conditions under which the meter is operating, and it follows that close watch of their work while in service must be given by an efficient man to insure a reasonably full registration of the water.

A falling off or an increase in the quantity of water registered by a certain property immediately calls for an explanation. Oftentimes the explanation is found on the slip. If the meter reader has been properly instructed and is conscientiously doing his part of the work, he has already noted the change in consumption and made inquiries or tests to determine the reason.

No attempt is made on the first or regular reading to ascertain the accuracy of the meter, as too much time is required, and the routes would come in unfinished, each route being made up on an average of 120 readings, which is considered a good day's work.

The aquaphone, however, must be used in every instance on the first reading. This is an invaluable accessory to the meter department. Each inspector is required at all times to carry one and after a reading of the meter is taken, contact is made to the meter or pipe near the meter to determine whether any water is passing that is not being registered. The record of this observation is indicated directly to the left of the reading by simply an "S" for still, "L" for leak, and "R" for running. In all cases the slips marked "L" and "R," where the quantity is not above normal, and all other records of doubtful quantities, are laid out for verification of readings and thorough investigation. On these "back calls" the aquaphone is again very useful in determining definitely whether an actual leakage exists without first inspecting all the plumbing. Time can be taken on these second calls to determine whether the "L" noted on the first reading was due to the final filling of a closet tank or an actual leak. Should there be a leak, the meter is timed for one tenth of a foot, if it is sensitive enough to record it, and if not, it is so stated on the inspection blank, and the meter is promptly taken out. In either case an inspection is made and the leak located. It is not uncommon also for the inspectors to report a leak which they estimate the meter is not fully registering. Where no leaks exist and the consumption is below normal, the meter is tested out for sensitiveness by attaching an orifice to a hose bibb or faucet, which is to be found on most any premises. This orifice passes a stream approximately equivalent to the average closet leak, allowance being made for difference in pressure of the various sections; the time required to register one tenth of a foot, or the fact that the meter failed to record it, are all noted on the slip directly opposite the reading.

We believe that very few faulty meters are missed during a reading that give the slightest sign as to their condition. All meters that will not register the average closet leak, or 300 gal. per twenty-four hours, are marked by the inspector for the attention of the superintendent, as we are satisfied that such small flows go to make up a large part of the total consumption.

During the meter reading period, the slips are turned in daily, and as stated are examined carefully by the meter superintendent, and the subtractions checked in ink. He makes a list for further

TABLE 1.

RECORD OF TEN $\frac{5}{8}$-INCH DISK METERS.

Dates.	Quantity Registered by Quarters in Cubic Feet.									
	1	2	3	4	5	6	7	8	9	10
1906–April	....	....	....	....	3 700	.....	.....	....	....	...
July	....	....	....	....	3 900	.....	.....	....	....	..
October	....	....	....	....	1 900	.....	14 200	....	....	....
1907–January	....	....	....	....	3 200	.....	22 500	....	....	....
April	....	....	....	2 200	2 800	.....	21 100	....	....	2 600
July	....	....	....	2 100	2 900	.....	12 900	1 600	....	1 500
October	....	....	....	3 100	1 700	.....	13 000	1 700	....	1 500
1908–January	5 000	....	2 200	2 800	2 500	8 500	12 900	2 100	....	1 600
April	1 600	....	4 300	2 500	2 500	6 900	11 900	1 800	....	1 700
July	2 100	3 300	2 300	3 100	2 600	1 000	5 100	2 100	....	1 800
October	2 500	4 000	1 900	3 000	1 700	4 600	7 700	1 400	....	1 500
1909–January	2 700	3 800	2 000	2 700	1 800	1 100	10 200	1 800	5 600	1 500
April	2 800	3 000	2 100	2 500	1 900	1 000	5 600	1 400	4 800	1 300
July	2 600	2 600	3 100	3 000	2 300	21 900*	4 700	1 100	5 400	1 600
October	2 500*	1 300	2 500	2 900	5 000*	24 600	15 200*	1 100	5 800	2 400*
1910–January	3 700	1 600	2 500	2 600	4 600	20 400	18 600	2 000*	3 500	2 100
April	4 200	1 300	2 800*	1 900	6 300	15 200	27 100	2 300	3 900	2 500
July	5 000	2 500*	4 500	3 100*	4 600	21 800	15 600	2 500	3 500	3 200
October	5 600	4 000	4 500	5 100	5 200	22 800	13 800	2 500	3 300	2 500
1911–January	3 900	3 400	4 800	4 100	5 300	20 700	12 700	2 200	5 500*	2 700
April	3 600	4 300	4 200	3 300	5 600	22 300	19 400	2 700	5 100	4 100
July	4 500	5 500	4 800	5 000	5 200	21 700	13 200	3 900	6 300	3 200
October		8 000	6 900	4 700	5 500	22 700	13 200	2 100	5 300	2 500
1912–January		2 300	6 300	4 700	5 200	22 000	9 600	2 200	6 400	3 300
April		2 300	5 200	4 300		25 700	19 400		6 700	3 700
July			5 900	5 200		27 200	15 400		7 000	
October			4 000	4 600		21 700	24 600		6 300	
1913–January			5 200	4 400		26 600	15 000			
April			4 300	4 600		21 300	15 600			
July			4 900	5 100		21 100				

* Indicates new meter.

examination and test in the field, and finally, from all the information turned in by the inspectors, the performance of the meter as indicated by the registration, and from his knowledge of the character of the property served by the meter, he determines at each reading the meters to be removed for test. This list is turned over to the plumbers or meter repair men for immediate attention as soon as a district is gone over, so that the removal of doubtful meters is going on continuously. After the reading and inspection, property owners are notified by postal of high consumption, and if the inspection shows the trouble, this is called to his attention. In this way not only are the bad meters removed promptly, but property owners are as promptly informed of leaks which cause waste and high bills.

To illustrate the method of arriving at meters to be removed and the results obtained, we have taken the record of ten meters, shown in Table 1.

Record No. 1 gives a total for seven quarters of 19 300 cu. ft. for the original meter and 28 500 cu. ft. for the first seven quarters on the new meter, or an increased registration of 50 per cent. In this particular case it was the period of service and not the record of registration that led us to remove the meter for test.

Record No. 2 shows a falling off in registration sufficient to excite suspicion, and a comparision of eight quarters gives 20 900 cu. ft. for the old meter, and 32 300 cu. ft. for a corresponding period for the new meter, or 54 per cent. increase in registration.

The third case shows an increase of almost 100 per cent. in registration.

The fourth column shows a meter caught early in its period of deterioration, but which shows for the first year of the new meter a gain of 50 per cent. in registration over the last year of the old meter.

Record No. 5 shows an example not so clear, but when corresponding quarters of succeeding years are compared, the record looks suspicious, and the record of the new meter justifies the conclusion that the meter was ready for removal for test, the new meter for the first year registering 170 per cent. more water than the old meter during its last year's service.

No. 6 gives a maximum of increase, and illustrates the possi-

bility of missing some poor meters for a long period, even when the greatest care is taken in the examination of the records. Here the increase for the year and a half shown is 450 per cent.

No. 7 shows an erratic consumption with a marked falling off, with an increase in registration for the year of 180 per cent.

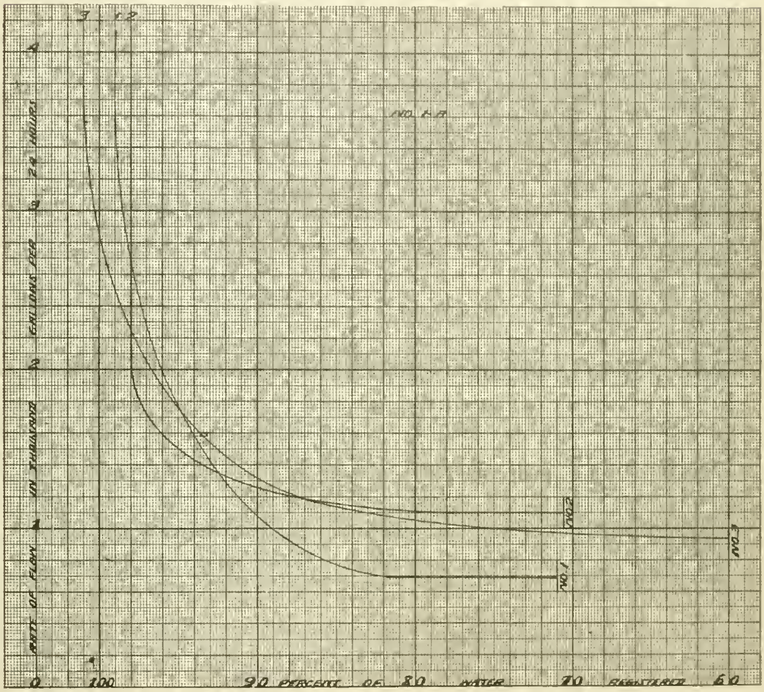


FIG. 1.
TESTS OF METERS REMOVED.

No. 8 shows a gradual falling off in registration, with about 100 per cent. increase.

Nos. 9 and 10 are typical cases of gradual falling off in registration, and the usual increase with the installation of a new meter.

Not all of the meters removed for test show a falling off in sensitiveness, but fully 75 per cent. of all selected are ready for over-

hauling, and the subsequent registration of the new meters shows results of which the examples given in Table 1 are typical. The conditions under which these meters were working did not change during the periods given, so the record shows a true comparison between the old and new meters.

To further illustrate graphically the necessity of watching the meters closely, and the results obtained when changes are made,

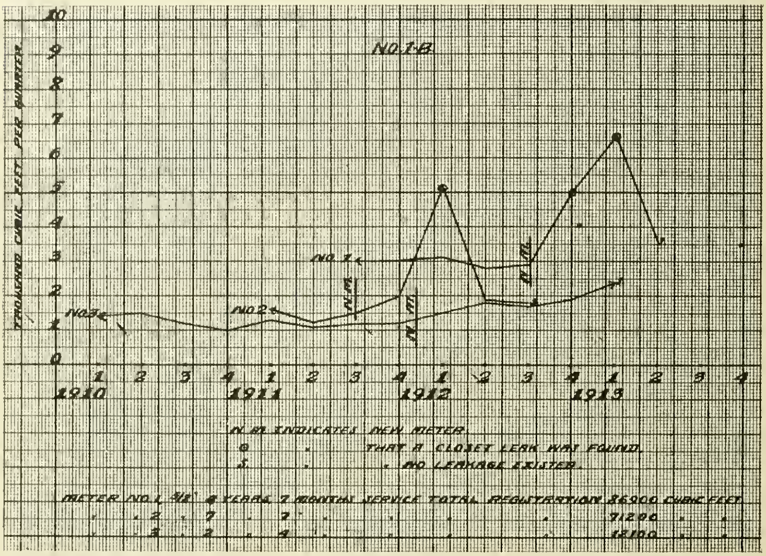


Fig. 2.
Sensitiveness of Meters Removed.

we have selected three typical cases, and Fig. 1 shows the test of meters removed, and Fig. 2 the registration of these meters and their sensitiveness. These meters are numbered 1, 2, and 3, for convenience.

No. 1 would not register on test a stream of 650 gal. per twenty-four hours, and its record curve for five quarters preceding its removal shows a uniform registration of about 3 000 cu. ft. per quarter. This meter came under suspicion by a comparison going further back than is shown on the curve. The record of the

new meter shows a decided increase of registration for two quarters, with a dropping back in the third quarter. The increase in the first and second quarters was due to leakage, which if the normal use was from 3 000 to 4 000 cu. ft. per quarter, amounted to from 2 000 to 3 000 cu. ft. per quarter, or from 200 to 250 gal. per day, a flow that was below the point of registration of the meter that had been removed, and this leak would not have been registered by the old meter. As a matter of fact, the leak had in all probability been going on for some time before the change of meters was made.

Meter No. 2 would not register on test a flow of 1 100 gal. per twenty-four hours, and consequently would not record a leak less than this amount. In this case the consumption record shows an increased registration of only 500 cu. ft. for the first quarter of the new meter, but catches a leakage of 3 000 cu. ft. per quarter during the next period, which in all probability the meter removed would not have picked up. The record seems to show that the normal registration has been increased from 500 to 1 000 cu. ft. per quarter by this change.

The curve of Meter No. 3 shows a registration down to about 1 000 gal. per twenty-four hours, and the record curves of this and the meter that replaced it, show a gain in one year of about 1 000 cu. ft. per quarter.

CAUSE OF LOSS IN SENSITIVENESS.

There are many causes contributing to the deterioration in effectiveness of the meter in service, — the gradual wearing of the working parts; clogging up by foreign substances such as white lead used by plumbers in the installation of service pipes; scale from service pipes; dirt stirred up in the distribution system by reversal of flows; flushing of pipes; dirt getting in pipes when extensions or repairs are made; etc. All of these things have their effect on the domestic meters. It remains for us to minimize the effect of these various causes of trouble by using care that little dirt gets in the pipes during construction, by flushing during periods when the house draft is at a minimum, by thoroughly flushing out service pipes when new meters are set, by avoiding the use of every material in the installation of service pipes that will clog a meter, and by the selection of the best type of meter for

particular services. In effect, to have in mind in all of our operations of the water plant, the possible effect of such operation on the meters, which must be kept in perfect condition if we are to get the best service possible from them.

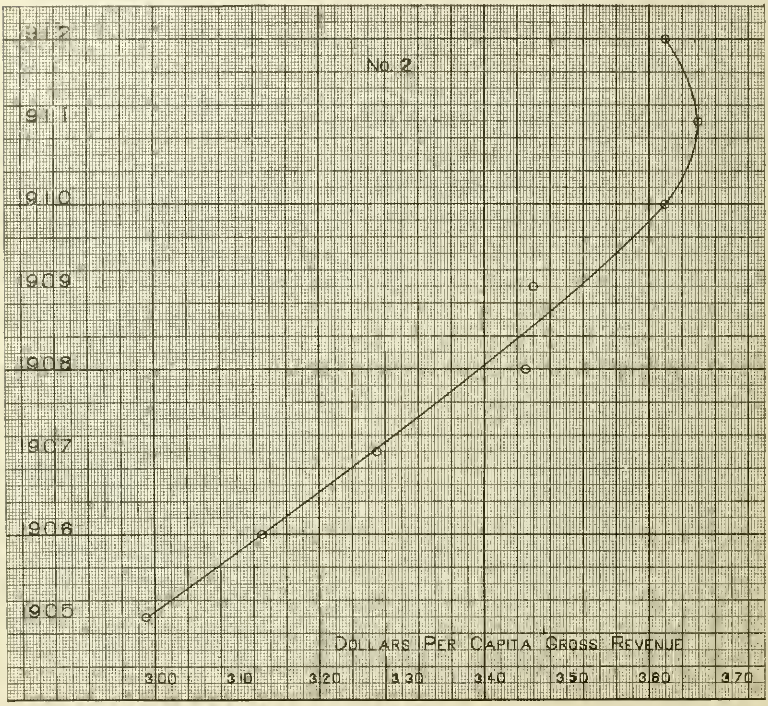


FIG. 3.
GROSS REVENUE PER CAPITA.

Now that we have considered the methods of caring for meters, the effect of neglect or proper care on their registration, the causes effecting conditions, and methods of minimizing deleterious effects, we will attempt to show the result of several years of careful attention to domestic meters on revenue.

Figure 3 shows gross revenue per capita for a period of eight years. This is the record of a residential town of about 24 000

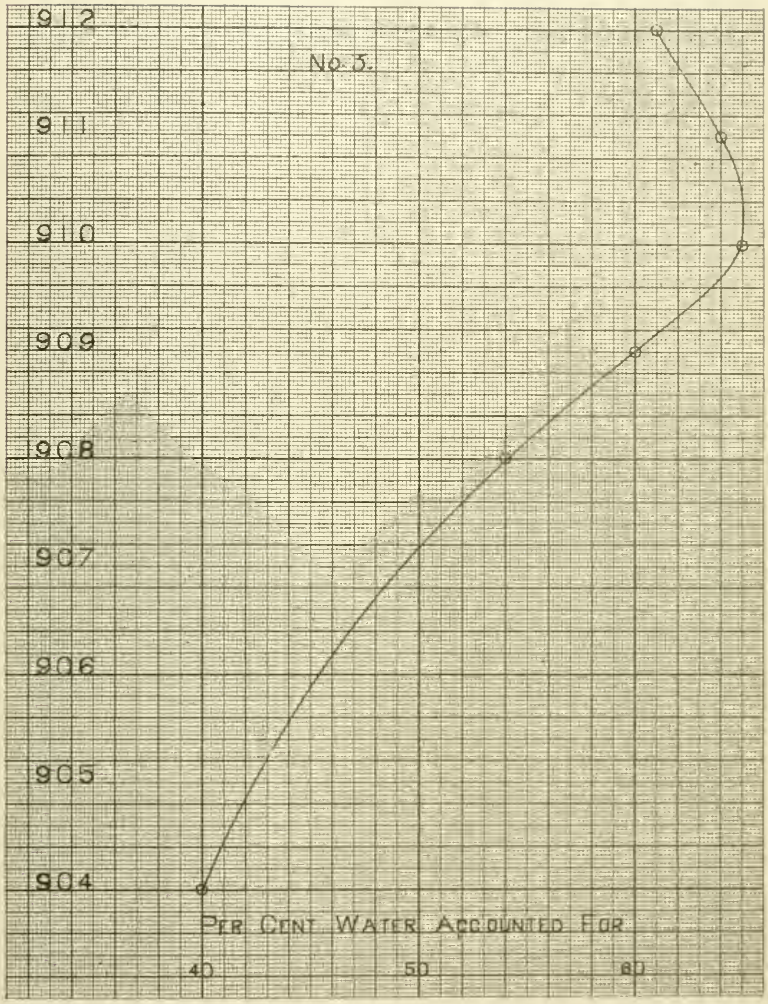


Fig. 4.
Per Cent. of Water Delivered Registered by Meters.

population with 4 200 meters in service in 1912. The town was completely metered in 1898, and between that time and 1906 no special care was given to the meters, except to remove one when it was stopped. About 1906 we began to give the meters more careful attention, as we then had in service in our various plants enough meters to require the whole time of one man to properly look after them. The results obtained in these early attempts to better conditions led us to make a very careful study of the subject, and conditions kept improving until 1910, when they seemed to indicate that we had arrived at about the normal condition, and the one that we should hope to maintain. The curve shows very well the growth of our knowledge about how to care for meters, gained through several years' experience. While we do not claim that the care of the meters was the only element entering into the raising of the gross revenue per capita, as shown by this curve, it was in our opinion the chief cause.

All of the connections in this town being metered, gave us an opportunity to make a comparison between the total registration of the domestic meters and the total quantity of water delivered to the town which was registered by Venturi meters, and since 1908 such comparisons have been made. One comparison made in 1904 enables us to plot this curve from that date. We are not at all proud of this record, as shown on Fig. 4, as the percentage of water accounted for is entirely too small. The conditions are particularly hard, — the distribution system being large in proportion to the population supplied, and the pressure ranging as high as 130 lb. A portion of the system is under direct pumping and the pressures are raised for fire service. Like the revenue curve, the care of the meters was not the only influence that affected this result, as during this period considerable work was done in detecting and stopping leaks in the distribution system and service pipes.

We consider this curve is worth showing in connection with this subject, in that it practically parallels the revenue curve, and we believe confirms our conclusions drawn from it.

In conclusion, we wish to say that the matter treated here is of necessity, to a certain extent, a repetition of the paper written for the New Orleans convention of the American Water Works Asso-

ciation, and is intended to show the practical result of following out the method of handling meters as described in that paper, and brought to date in this. It is written as a record of actual experience with the hope that it will be of some interest and benefit to the members of this Association.

DISCUSSION.

Mr. Theodore H. McKenzie. Mr. President, I would like to ask Mr. Cuddeback what the rate was per thousand gallons where the amount was about $3.40 to $3.60. Also, how often he tests meters.

Mr. Cuddeback. The rate is 30 cents per thousand gallons. We test all meters when they are first installed. We do not remove them for regular tests at any stated time. I have studied the subject very carefully and have come to the conclusion that the way we are handling it is the better method, rather than watching the performance of individual meters. If we adopted this latter course we would of necessity practically have to take out every meter over the course of eight or nine years.

Mr. McKenzie. Do you allow the meters to be set vertically?

Mr. Cuddeback. No, I do not allow them to be set vertically. I require them all to be set horizontally.

Mr. John C. Whitney. What rate would you call an average registering rate for a meter?

Mr. Cuddeback. Why, I think a meter should register between three and four hundred gallons every twenty-four hours.

Mr. Whitney. I think you are stating it rather high.

Mr. Cuddeback. Well, perhaps I am. I have made measurements of that with different meters, and we are pretty well satisfied if we are getting 300 gallons in twenty-four hours.

The President. I think this matter of revenue is one that is often lost sight of. Perhaps it is not so important in the municipal plant as it is in the privately owned plant.

Mr. William F. Sullivan. Mr. President, I would like to ask what effect the metering has upon the revenue. That is, what is the effect upon the revenue of abolishing flat rates and

adopting the meter system? I would also like to hear from some of those men who have given this matter attention.

MR. CUDDEBACK. I have had an opportunity of comparing towns similarly situated, — say, towns of a population of 100 000 — one completely metered and the other only partially metered, — and I have found that the revenue was about the same. I think the gross revenue is somewhat decreased by the installation of meters. There are many elements, however, entering into this question of whether the meter rate is comparable with the flat rate. I think that probably as a rule our meter rates are lower than our flat rates for the same service; and we get some of our reduction in revenue from that cause. My experience, however, is that net revenues will not be reduced by the installation of meters, but gross revenues may possibly be reduced. That seems rather strange, but we must take into consideration that the expense of installing meters and reading them and caring for them is offset by other expenses that are stopped when meters are installed. In a well-conducted plant, for instance, we should have a reasonable amount of inspection if we are going to keep our water consumption down. That expense offsets the meter reading and perhaps a good share of the care of the meter. There is also considerable expense saved in the reduction of pumping and additional investment for the plant to take care of increased consumption.

PROF. PHILANDER BETTS. Mr. President, I think another answer to that is that the result of adopting meters depends somewhat upon the class of customers who are metered at first. In Long Branch the Public Utilities Commission of New Jersey ordered the water company to install meters in connection with service to all hotels, bathhouses, industrial concerns, stock farms, greenhouses, and in all cases where the conditions were special. Without exception the bills were very materially increased after the meters were installed, but that was due to the fact that in all these special cases customers were using quantities of water far in excess of what the ordinary flat rates would pay for. In other words, before these meters were installed, there had been discrimination practiced in favor of these customers. I do not mean that the company was doing this with any idea of favoring them,

but that the ordinary flat rate schedules will not take care of boarding-houses, hotels, industrial establishments, dairies, steam laundries, and stock farms, and if properly applied, flat rates will produce gross bills so high that it will occasion considerable dispute. In Long Branch the disputes due to the increase in practically all of the bills to these different customers have not yet ceased.

The Long Branch Company meters very few customers. The business is very large, and it has practically all been carried on at a flat rate. The company is receiving a very large revenue, but notwithstanding that, the amount of money that is actually left over for net income as a profit on the investment is very small. The company has just been able to pay an ordinary interest rate in the last few years. The solution of that company's difficulties lies finally in the adoption of meters for all service. What will then result in connection with the majority of customers (beyond those to whom meters have already been applied) will be, to my mind, without question, a reduction in the gross revenue. There will also be a very material reduction in the operating expenses, with the probable result that the company will have more money left over with which to pay the interest on the investment.

The case of the Long Branch Company is typical of that of a good many who have hesitated for years in the adoption of meters. I mention this point regarding this particular company because we have probably had more complaints against that company than against any other company in the state of New Jersey. In this connection it is shown that the conditions there are due very largely to the lack of meters.

There must invariably be a period of a great deal of trouble in any situation like that; but in perhaps a year or so after meters are once installed the customers become used to them and adapt their water usage accordingly, and then the conditions are very much better than before. To show the contrast, I might say that in another set of companies with which Mr. Cuddeback is very familiar, where the great majority of the customers are metered, there have been practically no complaints at all in regard to the bills rendered.

MR. CUDDEBACK. Mr. President, our experience in Paterson in comparing rates has been this. For the last fifteen years we have been metering all new connections, and those applying for meters. In those applying for meters during that period, about 90 per cent. have had a reduction in their annual water bills by the installation of meters, as against the flat rate bill that they formerly paid. That is the only comparison we could make. But in looking at those figures we must take into consideration the fact that only those customers applied for meters who thought that they could make a reduction in their bills by having meters installed.

MR. GEORGE A. KING. I think that Mr. Cuddeback has given us some excellent practical points in connection with the care of our meters, but to what he suggests I would add a periodic testing and cleaning of the meters. A meter may begin to go slow and go down to recording only 50 per cent. of the actual consumption before the fact that it is going slow is noted, with the periodic testing of meters that may be overcome. I think that this should be added to Mr. Cuddeback's list of the care to be given meters.

MR. CUDDEBACK. A meter is almost as apt to go slow within a year after it is set, or go wrong within a month after it is set, as it is to do so within two years or three years. That is, the period which you select to take out your meters for general testing would not reach any appreciable percentage of those that go wrong, and you get better results by carefully watching the individual performance of the meters. A great many meters are taken out within a year after they are set. I feel that some rule like this might be applicable: Say, within a period of eight years (just to set a time) any meter that has not been overhauled during that period should then perhaps come out.

MR. KING. I would make it four years.

MR. W. C. HAWLEY. While discussing this matter of meters I would like to ask if any one has had the experience such as we are having at the present time, of meters running fast. Since we have installed our filter plant we have been up against that proposition, particularly within the last nine months or a year. Prior to that time I believed — and I have expressed the opinion a

great many times — that practically no meter over-registered if it has been properly tested before setting. But I have been obliged to change my mind on that subject. It is not true of all the makes, but we have two makes in particular that we have been having trouble with. It has become so serious that we are taking out every one of those two makes, bringing them to the shop and retesting them. As far as I can tell, it is a case of the disk not fitting the disk chamber closely in all parts of its oscillation. The meter is tested, and put in registering properly; by and by that space between the disk and the disk chamber begins to fill up with silt or an organic growth, and that meter will run three, four, five, and in very exceptional cases 12 per cent. fast. When a customer kicks about his bill and you test his meter and show him that it is 10 to 12 per cent. fast, there is trouble.

The President. That's an extraordinary thing in my experience, for a water meter to run fast.

Mr. Francis T. Kemble. We have had some experience in that way, the chamber filling with sediment, — particularly in low spots where the sediment would amount to something, — and the meter running just about that point — three, four, or five per cent.

Mr. John C. Trautwine, Jr. The author's diagrams, Figs. 3 and 4, are beautifully convincing as to the beneficial results of "The Care and Maintenance of Meters" between the years 1904 or 1905, and the years 1910 or 1911; but, beyond the latter point, each curve seems no less convincing as to the inauguration of a period of retrogression, and I must congratulate the author upon the optimism which has enabled him apparently to overlook this feature.

Referring to Fig. 3, the author says: "Conditions kept improving until 1910, when they seemed to indicate that we had arrived at about the normal condition, and the one that we should hope to maintain."

Referring to Fig. 4, he says, indeed: "We are not at all proud of this record, as shown on Fig. 4, as the percentage of water accounted for is entirely too small"; but this seems to refer to the diagram as a whole, and merely to admit that from 40 to 65 per cent. of water accounted for "is entirely too small."

Neither reference makes any allusion to the rather obvious drop in the curve, beginning at about 1910 or 1911.

MR. CUDDEBACK. The curve is on such a scale that the variation in the last three years is only two cents per capita. The variation in the period from 1906 up to 1910 is some 45 cents per capita. I think perhaps that answers you.

I didn't dwell with any optimism on that second curve. I simply showed it to show how bad the distribution could be.

I might say, Mr. President, that we have had a very few examples exactly like Mr. Hawley describes; nothing that can be described as an epidemic, but we have had individual cases where meters over-registered as high as 6 per cent., and I judged from the same causes exactly as he gives. But it was nothing of a serious nature, not nearly one per cent. of the meters over register.

MR. MCKENZIE. How do you determine that they over-register?

MR. CUDDEBACK. By a volumetric test.

CLEANING WATER MAINS AT HARTFORD, CONN.

BY CALEB M. SAVILLE, CHIEF ENGINEER, BOARD OF WATER COMMISSIONERS, HARTFORD, CONN.

[*Read November 12, 1913.*]

The city of Hartford, Conn., is supplied with water by gravity from a system of six reservoirs in West Hartford, distant about $6\frac{1}{2}$ miles from Hartford City Hall. Nearly twelve miles of watershed are tributary to this system, the drainage from all of which finally flows to Reservoir No. 1. The effluent gatehouse is located at the base of the dam of this reservoir, and from it lead the three mains which supply the city, two 20-in. and one 30-in. The first main laid was of the well-known cement-lined character, and was put into service in 1867. On account of frequent breaks, portions were replaced from time to time with cast-iron until now this is wholly a cast-iron line. Although the older in point of original location, this main is actually the lesser in age of the two 20-in. mains. In speaking of this main hereafter, it will be known as the south 20-in. main. The other, known hereafter as the north 20-in., was laid in 1875, and is therefore about thirty-seven years old. The 30-in. main was laid in 1896 and is sixteen years old.

The average consumption for the year 1911 was at a rate of 8 051 000 gal. per day. The maximum monthly rate in 1912 was 9 245 000 gal. per day, the maximum rate at any period during the day being about 13 700 000 gal., while the minimum flow from midnight to 5.00 A.M. was at a rate of 4 500 000 gal. per day. The drop in pressure at City Hall due to this difference in rate was 18 lb. before cleaning, and the gain due to the cleaning of one 20-in. main is estimated to be from 2 to 3 lb., the actual loss with the same flow under present conditions being from 15 to 16 lb. For the preliminary study, simultaneous measurements were taken in all three of the mains at the time of average daily flow. Previous to these tests the 30-in. Venturi meter on the supply line and the pitometers used in the work were checked against each other, the pitometers being found to read about 1.5 per

cent. in excess of the meter reading. The results of the preliminary tests on the mains have been summarized and are given in Table 1, together with certain comparisons that relate to age, carrying capacity, and present conditions of these supply mains:

TABLE 1.

Diameter.	When Laid.	Coefficient for Kutter's Formula as per Weston.			Discharge in m.g.d. Loss of head, 18 lb.			Age.	
		Existing.	According to Age.	New Laid or Cleaned.	Present.	New Laid or Cleaned.	After Ten Years.	As per Coefficient.	Actual.
30-in.	1896	81.6	91.5	112	8.5	11.7	10.2	28	16
North 20-in.	1875	63.4	75.0	111	2.4	4.2	3.7	65	37
South 20-in.	1867	73.5	75.0	111	2.8	4.2	3.7	40	25–40
					13.7	20.1	17.6		

NOTE: Date of laying south 20-in. main is date original main was laid. Portions later relaid.

From the above it was seen that the coefficients (Column 3) for the 30-in. and the north 20-in. mains were unusually low, while the south 20-in. main was in about the condition that might have been expected. If these pipes were cleaned, it was estimated that the present system should be capable of delivering 20 million gal. per day to the city with the same loss of head that then existed (18 lb. at City Hall); and, if not cleaned, it appeared that under present conditions of demand the construction of a new main would be an immediate necessity.

Using the consumption figures from the Venturi meter record for June, 1912, the following estimate of future consumption was made: Average rate, 9.13 million gal. per day and maximum rate, 14.5 million gal per day, or 58 per cent. excess maximum to average rate. At an average annual rate of increase of 500 000 gal. per day, in five years the additional amount required would be 11.63 m.g.d. and 18.4 m.g.d. respectively for average and maximum drafts. Therefore, if the above assumptions are correct and if

the present system could be restored to its original capacity, it should be good for five years more, even with a rate of deterioration twice that usually assumed. (See totals in table above.)

If a new supply pipe were laid, it would be at least 36 in. in diameter and about 33 000 ft. long (about $6\frac{1}{4}$ miles). At a minimum price of $8.25 per linear foot, this line would cost about $270 000, the interest on which at 5 per cent. simple interest would be $13 500 per year, and at compound interest the charge would be $74 500 in five years.

The preliminary estimate for cleaning three miles of 30-in. and six miles of 20-in. was $15 300, a little more than the interest for one year on the amount necessary to lay a new 36-in. main. If, therefore, the construction of the latter main could be put off for five years without detriment to the service, the saving to the city was estimated to be about $60 000.

On account of the benefit which would result to the city if it were possible even partially to restore the carrying capacity of the existing mains by cleaning them, information was sought from various cities where the process had been applied. Very courteous and complete replies were received, and there seemed to be a unanimity of opinion that the work done was successful in operation and satisfactory in result. Some of the cities from which replies were received were:

City.	Sizes Cleaned. Inches.	Remarks.
Cincinnati, Ohio	6 to 16	Third contract for work.
Rochester, N. Y.	6 to 20	About 25 miles cleaned in all.
Newton, Mass.	24	
St. Louis, Mo.	15 and 20	
Brooklyn, N. Y.	6 to 36	
Atlanta, Ga.	30	
Am. W. W. & Guar. Co.	4 to 20	40 to 50 miles cleaned this season.

The list prices quoted by the National Water Main Cleaning Company of New York for doing work in the distribution system were:

PRICES PER LINEAR FOOT OF PIPE.

6-in. . . . . . . .16 cents	12-in. . . . . .22 cents	24-in. . . . . .40 cents
8-in. . . . . . . .17 cents	16-in. . . . . .26 cents	30-in. . . . . .65 cents
10-in. . . . . . . .18 cents	20-in. . . . . .30 cents	36-in. . . . . .80 cents

These were stated to be for average conditions for lengths of five miles or more given only for purposes of preliminary estimate, and were submitted with the reservation that local conditions might cause considerable variation either way. In Hartford a price of 28 cents per linear foor for 20-in. was given for a three-mile contract, with a further reduction if a greater length was cleaned. The conditions were exceedingly favorable for a large part of the way on account of few consumers on the line, advantageous location of gate valves and blow-offs for cutting out sections of proper length, and also because of a parallel main with cross-connections which gave ample water for operating the machine without interference with the city supply.

A contract was entered into September 4, 1912, with the National Water Main Cleaning Company to clean, on trial, three miles of 20-in. pipe, and if satisfactory results were obtained the cleaning process might be continued through several miles additional of 20-in. and three miles of 30-in. pipe.

Work was begun September 6 and suspended on October 24 on account of scarcity of water in the reservoirs. The results were very satisfactory, and during this period (forty-nine days) a total of 33 093 ft. ($6\frac{1}{4}$ miles) was cleaned. On this section there were 154 service pipes which were shut off during cleaning, and only four were at all interfered with by the cleaning operations. Three of these were extension meters located at the street line with no curb cocks, and it was necessary to remove the meter and clean out the dirt. The other service affected was plugged but was easily relieved by a force pump. The following is a typical log of the operations:

October 15. Location, Farmington Avenue and Asylum Street, Sigourney Street to Ford Street. Distance, 2 747 linear ft.

During afternoon, 20-in. pipe exposed at Sigourney Street and at Union Place. Cleaning machine put into a 9-ft. piece of pipe and ready for insertion into the pipe line when cut was made.

8.30 P.M. Section, Gillette Street to Cathedral shut down.

9.40 P.M. Above section completely drained. Cutting began at this time at Sigourney Street.

FIG. 1.

FIG. 2.
THE MACHINE USED IN CLEANING 20-INCH PIPE.

1.00 A.M.	Section, Cathedral to Ford Street shut down.
2.00 A.M.	Pipe cut out at Union Place and riser wedged into place.
2.33 A.M.	Gate opened at Gillette Street to start machine.
2.50 A.M.	Machine reached Union Place.
5.00 A.M.	Machine having become wedged in riser, pipe was removed at this time.
6.25 A.M.	Section closed in, joints made up, and water turned into section.

The usual force employed on this work was a superintendent, a foreman, a calker, fourteen laborers, and a double team for carting pipe materials and supplies.

Under average conditions 3 000 ft. was found to be the maximum effective length for cleaning. The contractor stated that 5 000 ft. had been successfully cleaned by him elsewhere, although in some places it had been possible to go only 1 500 ft. at a time, using water to drive the machine. If the machine were drawn through by a cable, the length of section is from 500 to 1 200 ft. It is stated that the machine can be operated by water under heads of as low as 10 or 12 lb. The least available head on the Hartford lines was somewhat greater than this.

The pipe machine used in cleaning the mains (Fig. 1) consists of three distinct sections attached to each other by a flexible joint in the connecting shaft which is central in all of the sections. These joints move readily and allow the machine to pass through ordinary water pipe curves if the radius is not too short. The first section consists of three spiders fastened to the shaft; these are armed with saw-tooth blades that project at right angles to the axis of the machine. The function of these blades is to cut up and tear loose incrustation and scale that adheres to the pipe walls.

The second section is made up of two spiders armed with smooth scrapers. The function of these blades is to scrape away all matter left clinging to the pipe by the first section.

Behind these two sections is a double piston fitting the pipe very closely, with leather gaskets pressed out by steel springs which are continuous around the entire circumference. The pistons are fitted with dampers which can be adjusted to the pressure of water and so regulate the quantity needed to wash ahead the scale and other matters cleaned from the pipe. Behind each spider, and loosely fitting on the center shaft, are

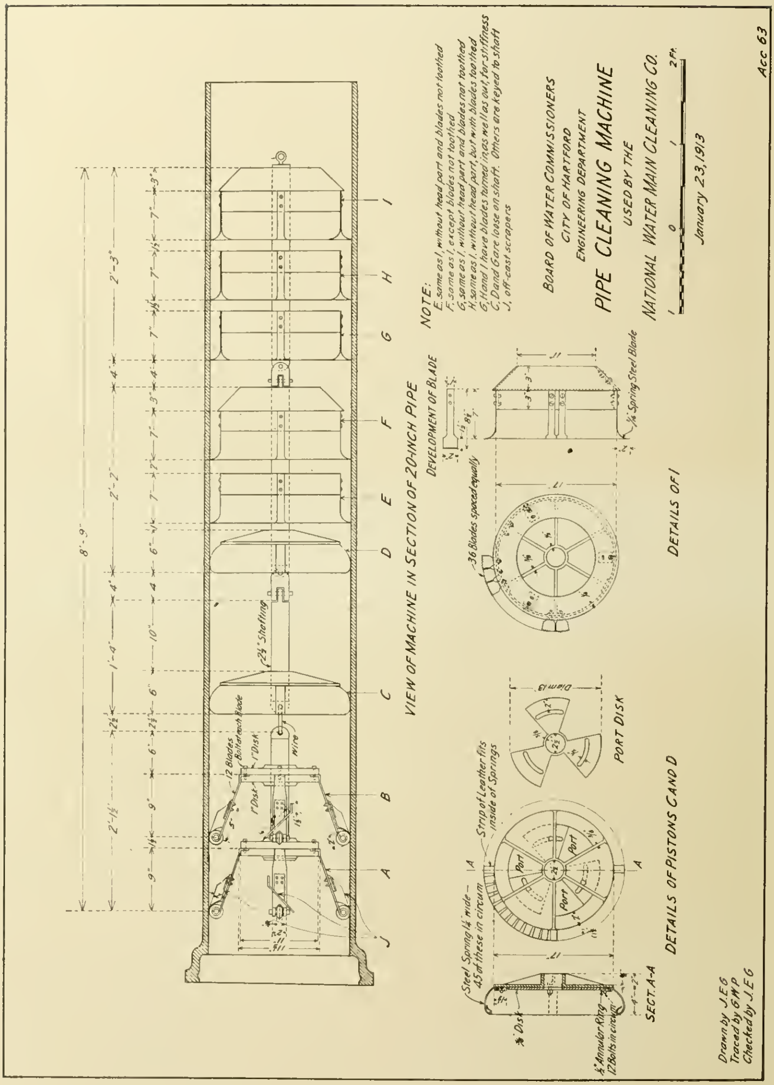

VIEW OF MACHINE IN SECTION OF 20-INCH PIPE
NOTE:
E, same as I, without head part and blades not toothed
F, same as I, except blades not toothed
G, same as I, without head part and blades not toothed
H, same as I, without head part, but with blades toothed
G, H and I have blades turned in as well as out for stiffness
C, D and G are loose on shaft. Others are keyed to shaft
J, off-cast scrapers
BOARD OF WATER COMMISSIONERS
CITY OF HARTFORD
ENGINEERING DEPARTMENT
PIPE CLEANING MACHINE
USED BY THE
NATIONAL WATER MAIN CLEANING CO.
January 23, 1913
Acc 63
DEVELOPMENT OF BLADE
DETAILS OF I
PORT DISK
DETAILS OF PISTONS C AND D
SECT. A-A
36 Blades spaced equally
Drawn by J.E.G
Traced by G.W.P
Checked by J.E.G

FIG. 1.

FIG. 1.

FIG. 2.
THE MACHINE USED IN CLEANING 20-INCH PIPE.

three somewhat flexible metal disks whose function it is to deflect the wash water towards the pipe walls and out through the cleaning blades, where the high velocity helps remove some matter and keeps the whole mass moving along with the machine.

Behind the pistons is another section which carries two rows of right and left off-cast scrapers. There are very heavy and are designed to smooth off the surface and leave a clean, smooth water way. These blades are allowed only just to touch the pipe walls, their position being kept by case-hardened rollers that run on the pipe wall. The gross diameter of the machine used on the 20-in. mains is $21\frac{1}{2}$ in., the steel springs letting down at entrance and so keeping the machine firmly centered in the pipe. The steel blades are made especially for this purpose and are nearly all replaced after each draw. This replacement, of course, depends largely on the character of the incrustation, and when mud alone is found, the blades may require very little renewal.

Previous to the cleaning work a very thorough survey was made of the capacity of the pipe line by the use of the pitometer, and similar tests were made after the work was finished. A typical summary of the results of this work is given below.

Pipe cleaned: North 20-in. main, Farmington Avenue.
Section: Reservoir No. 1 to Vanderbilt Hill.
Length: First test, 16 400 ft. Second test, 14 650 feet.
Pipe laid in 1875. Age: Thirty-seven years. Kind: Cast iron.

	(1)		(2)
Date of test	August 22, 1912		October 2, 1912
Make of gage	Crosby		American
Unit of gage	1 lb.		1 ft.
Head lost, ft.	20 to 55		20 to 50
Range of velocity (ft. per sec.)	1.69 to 2.40		2.84 to 3.97
Possible error in coefficient	Per lb. 3%		Per ft. 1.5%
Mean coefficient; Chezy formula	69		111
Increase in capacity	—	61%	—
Average coefficient in Chezy formula	Weston (37 y.), 75 Williams and Hazen (37 y.), 73		(New) 111 (New) 116

The loss of head was about the same in both cases, and sufficiently large so that an error of one pound or one foot would be comparatively negligible.

The north 20-in. main was cleaned from the reservoir to Union Place, a distance of about five miles. The south 20-in. main has been cleaned from the reservoir east about $1\frac{1}{4}$ miles. Tests of the flow made before and after cleaning indicated that in both pipes the carrying capacity had increased sufficiently to compare

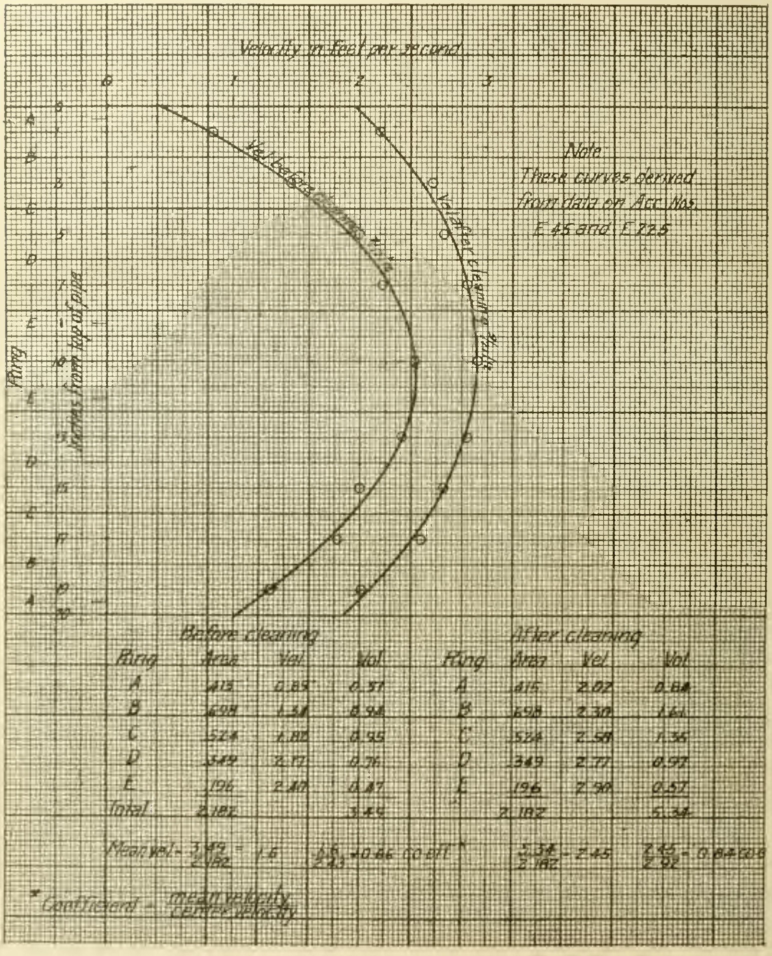


FIG. 2.

CURVES SHOWING THE EFFECT OF CLEANING UPON THE VELOCITY.

FIG. 1.
BEFORE CLEANING.

FIG. 2.
AFTER CLEANING.

[From the *Municipal Journal*.]

with Weston's tables for new 20-in. pipes. This is equivalent to a coefficient of 111 in the Chezy formula, the resulting increase in capacity being 61 per cent. and 50 per cent. respectively for the north and south 20-in. mains. Several readings of the amounts of water used during the cleaning were made from the records of the Venturi meter at the reservoir gate-house, and the following quantity is believed to be a reliable estimate of the amount per linear foot:

Quantity required to fill 1 ft. of 20-in. pipe	16.3 gal.
Quantity used in cleaning	24 gal.
Adding 25 per cent. for emergencies, etc.	9.7 gal.
Total estimated amount per linear foot	50.0 gal.

The total distance cleaned was 33 093 ft. ($6\frac{1}{4}$ miles), and it is estimated that 1 655 000 gal. of water were used. This amount is about one fifth of one day's supply to the city. Table 2 presents a summary of the work done and the results obtained:

A diagram (Fig. 2) is included for the purpose of showing the results of cleaning on the velocity. The references to "Ring," "Area," etc., are to the method and nomenclature given in the "Tables and Directions" of the Pitometer Company. In this connection it may be said that the incrustation removed was in places over an inch thick nearly around the pipe. Besides this, considerable quantities of pipe moss (Paludicella) were found near the reservoir end of the mains.

On account of a suggestion that the cleaning of water mains might have effect in causing or aggravating the so-called "red water" trouble, samples from the cleaned and uncleaned mains were sent to Mr. Jas. A. Newlands * with the request that especial attention be given in his examination to detecting any indications of "red water." The following extracts are given from Mr. Newland's reports on the samples submitted:

Report on Sample No. 1352 (sample taken October 1, 1912 from 20-in. main that has been cleaned):

"This sample, which I understand is taken from the clean main section, shows only very slight differences from Sample No. 1353

* Consulting chemist and bacteriologist, Middletown, Conn., and chemist of the Connecticut State Board of Health.

TABLE 2.

Location.	Date Tested.	Length, Feet.	Range of Flows, M.g.p.d.	Lost Head per 1 000 Ft.	Chezy Coefficient.
			Northerly 20-in. Main.		
Reservoir to LeMay's.					
Before cleaning	8/31/12	5 450	3.3 to 4.7	2.90 to 7.65	60 to 67
After cleaning	9/21/12	5 450	3.6 to 5.3	0.64 to 2.09	124 to 159
After cleaning	9/26/12	5 450	2.5 to 5.3	0.96 to 2.57	109 to 125
LeMay's to West Hartford Center.					
Before cleaning	9/14/12	4 430	2.8 to 4.2	3.80 to 7.00	50 to 56
After cleaning	9/26/12	3 750	3.6 to 5.2	1.70 to 2.90	94 to 115
West Hartford Center to Highland Street.					
Before cleaning	9/10/12	6 420	3.1 to 5.8	2.03 to 8.46	69 to 75
Vanderbilt Hill to Broad Street.					
Before cleaning	10/3/12	10 180	2.4 to 4.3	1.81 to 5.81	61 to 65
West Hartford Center to Vanderbilt Hill.					
After cleaning	10/2/12	5 450	4.0 to 5.6	1.18 to 3.63	102 to 128
Reservoir to Highland Street.					
Before cleaning	8/27/12	16 300	2.4 to 3.4	1.40 to 2.89	67 to 70
Reservoir to Vanderbilt Hill.					
After cleaning	10/2/12	14 650	4.0 to 5.6	1.55 to 3.01	110 to 112
			Southerly 20-in. Main.		
Reservoir to Highland Street.					
Before cleaning	8/27/12	16 300	2.58 to 3.91	1.52 to 3.35	73 to 75
Before cleaning	10/14/12	16 300	3.25 to 4.08	2.17 to 3.44	76.3 to 76.6
Reservoir to Westland Street.					
After cleaning	10/28/12	6 400	4.1 to 5.4	1.61 to 2.70	110 to 119

taken from the uncleaned main, and these differences are so slight as to be within the limits of laboratory error and the slight variation which might be expected in two samples from different points in the same pipe line. On a long line of cleaned pipe we might expect that, where the inner surface had been cleaned down to the

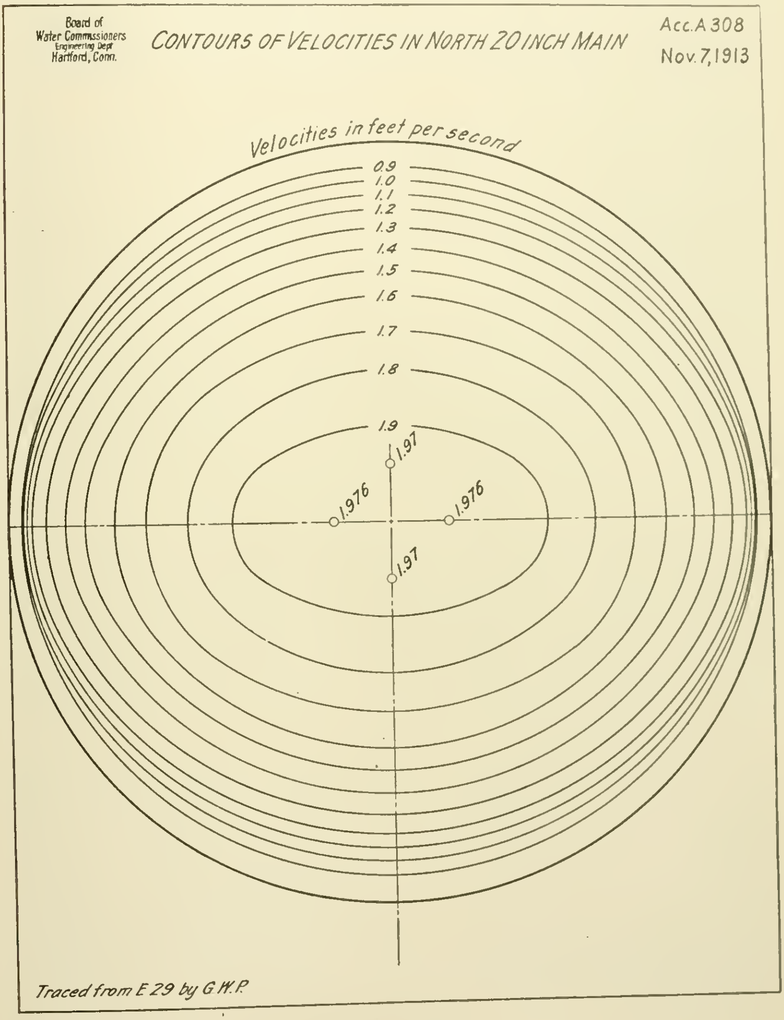


FIG. 3.

iron, at such points there would be some reductions of the oxide of iron by the action of decomposing algæ growths and other organic matter. This would result in iron being taken up by the water and a consequent increase in color. As the amount of dissolved oxygen in this water is probably high enough at all times to supply the oxygen required by the organic matter, there probably will be no appreciable effect on the color and iron content of the water. These samples show none, the color being the same in both cases, while the iron amounted to .3 part per million in this sample and .2 part in Sample 1353."

Letter of October 7, 1912: "With reference to the tap and hydrant samples, I will say that the results obtained do not show any appreciable effect of the cleaned main [on] the appearance or quality of the water. Under some conditions, as I have suggested, it is quite possible that for a time there might be some increase in color and iron matter content, due to the action of decomposing organic matter on the fresh iron with which it comes in contact, but the amount of organic matter in your reservoirs does not usually become great enough to exhaust the oxygen dissolved in the water, and I do not anticipate any material effect on the color of the water. However, it is difficult to determine how the various types of water will act under varying conditions, and I think it will be worth while to keep track of the relative colors of the waters in the cleaned and the uncleaned mains as the work goes on."

Report on Sample No. 1378 (taken October 28, 1912, from south 20-in. main that had been cleaned): "These results show practically no differences in the physical appearance of the chemical constituents of the water as compared with Sample No. 1370 taken from the north 20-in. main. No differences were noted in the color, turbidity, or sediment of the two samples, although we might expect slight differences even in two samples taken from different points in the same main. There is no indication at this time that cleaning the main has resulted in the beginning of 'red-water' trouble."

Letter of November 4, 1912: "I have looked the samples over carefully for evidence of 'red-water' trouble, but there appears to be no such effect at this time. The results on the two samples are more nearly alike than we usually find them, as it frequently happens that samples, although taken from two points on the same main, will show some differences in the amount of turbidity and sediment especially, due to unavoidable differences in the amount of sediment stirred up when the samples are taken. There is no evidence in these results, therefore, to show that the cleaned main has any effect on the appearance of the water at this time."

Some criticism of the work was made by a writer in one of the local newspapers that the cleaning of the pipes destroyed the inner coating, and the intimation was that the rusting of the mains would probably proceed very much more rapidly in the future than in the past. It has been stated by some engineers that the cleaning of cast-iron pipe frequently does increase the rate of tuberculation, and under some conditions that may be true. Previous to undertaking the Hartford work, inquiry was made concerning this matter of various water departments where the pipe had been cleaned. Very little information was obtained regarding the rate of returning incrustation, but regarding the removal of the coating, the opinion of all who had made examination was that the inside of the pipe was uninjured. Observations made on the ground showed no evidence of damage of this kind. The hardest test probably was encountered when the machine was pulled into the 9-ft. piece of pipe made ready for insertion in the line. In several cases this section was examined and no removal of the coating was apparent.

The following is a copy of the specifications under which the work was done.

Specifications.

The contractor shall clean and remove deposits and tubercular growth from all mains herein specified or any part thereof as directed by the chief engineer of the party of the second part, and in accord with the proposal on page 4, the location of said mains being shown in plans on file at the office of the said chief engineer, by its patented process and under the following specifications and terms:

The contractor shall provide the necessary tools, appliances, labor, and materials to perform and complete this work in an expeditious manner. The work to be done shall consist of excavating, cutting pipe to be cleaned, cleaning the pipe so as to remove rust, tubercles, organic growths, deposits, silt, and other foreign material due to the presence of water in the mains, reconecting the pipe, and refilling the holes.

The contractor shall make all necessary excavations for the execution of the work. The materials excavated from the openings thus made shall be placed in such a position as not to impede travel on the railroads, or unnecessarily impede the travel on the streets in which the openings are made.

The contractor shall take proper precautions to support and sustain the sewers, conduits, water and gas mains laid in or across the streets which may be liable to injury or damage from digging the openings herein mentioned, and have a sufficient quantity of timber and plank on the ground when necessary to use the same as required. All sheet plank and timber used during the progress of the work to support the sides shall be removed as the filling proceeds.

The contractor shall refill the openings and remove all surplus material. The openings thus made shall be filled with suitable material, put in horizontal layers not over six (6) inches thick, and each layer thoroughly rammed so as to render the whole filling solid and compact.

The contractor shall maintain at all openings made by them such guards and lights as may be necessary to prevent accident or injury to the person or property of others; and shall indemnify and save harmless the Water Department against any and all suits and actions brought against it, and from all damages, costs, and expense to which it may be put by reason of any negligence or carelessness in the performance of the work, or in guarding same, or by or on account of any act or omission of the contractor or its agents, except as herein specified and provided.

The Water Department shall furnish right-of-way and permits where same are necessary for breaking of pavements.

The Water Department shall notify all consumers in advance to shut-offs and shall assume all responsibility for such shut-offs, and save the contractor harmless from all damages, costs, and expenses incurred by reason of injury or damage to the person or property of another as a result of shut-offs.

On completion of the cleaning of each separate section the Water Department shall make immediate inquiry of each consumer as to any stoppage of flow in service pipes, and the Water Department shall immediately notify the contractor of any such stoppage, and the contractor shall at once remove any stoppage due to said cleaning operation. The house services shall have been shut-off at the curb or just inside the cellar wall, by the Water Department so far as possible, before the cleaning operation shall have been commenced, and should the Water Department fail to notify the contractor of any such stoppage within one week from the time the water is turned on to the section where such stoppage occurs, the contractor shall not be held responsible nor be required to repair same.

The Water Department shall not hold the contractor responsible for cutting pavements or excavations when due to incorrect maps or information as to the size and location of pipes, and the

contractor shall be reimbursed for extra labor entailed thereby, plus fifteen per cent. (15%) for contingencies.

The Water Department shall also reimburse the contractor for the actual cost and expense entailed in cutting pavements, making excavations, cutting and replacing mains to remove the cleaning equipment when same becomes necessary as a result of defective joints, surplus lead, bends, offsets, or special fittings which do not conform to the size of the main being cleaned, or are not shown on the plans.

The Water Department shall furnish one or more competent men to take charge of all shut-offs, and to promptly make such shut-offs when requested by the contractor or its representatives.

The contractor shall notify the Water Department when shut-offs are wanted.

The Water Department shall coöperate with the contractor, and assist in expediting the work of the contractor, by giving prompt shut-offs whenever requested by the contractor, and furnishing normal pressure in the mains and when necessary and possible to give higher pressure.

The contractor shall coöperate with the Water Department and assist them whenever possible to accommodate their consumers.

The Water Department shall not hold the contractor liable for any damages caused to its gates, valves, or hydrants by reason of their necessary operation in making shut-offs, or their operation under the direction of the Water Department.

The Water Department shall repave all openings for the cleaning and shall be responsible for such repaving.

The contractor shall make regular detailed statements of all overtime or extra materials which may be chargeable to the Water Department, giving the cost of materials and rate of pay of its employees plus fifteen per cent. (15%) for contingencies.

The contractor shall assume responsibilities for any claims made against the Water Department for any infringement of patents by the use of patented articles in the execution and completion of the work, and shall indemnify the Water Department for all costs, expenses, and damages which the Water Department shall be obliged to pay by reason of any infringement of patents used in said work.

Any damage done to the mains at joints where cuts shall have been made for the cleaning work shall be repaired and made fairly secure and tight by the contractor so as to be in first-class, serviceable condition at the completion of the work.

In reconstruction, the contractor will use such classes of pipe and special castings conforming to the New England Water Works Standard as may be designated by the chief engineer.

So far as possible, the work to be done nights and Sundays in order to avoid annoyance to consumers.

Plates XXXIII and XXXIV show views of the cleaning machine taken at different angles.

Diagrams 2 and 3 are given merely to show the velocity conditions existing inside the uncleaned pipes. Pitometer traverses were made on both the vertical and horizontal diameters of each. The north 20-in. main has been laid sixteen years.

Discussion.

Mr. Frank L. Fuller. I would like to ask how small a pipe it is feasible to clean in this way.

Mr. Saville. I cannot answer that. Our mains were all 20-in. in diameter.

Mr. Burt Bradley Hodgman.* There have been a great many 3-in. mains cleaned, but we do not pretend to clean anything smaller than that. Most of the work is on 6-in. and larger.

Mr. Miller. Where a city has only one main and no storage, or only storage enough for twenty-four hours, how will this thing work?

Mr. Saville. It took from half past eight at night to about half past six the next morning to clean our supply main, so that it was out of service for nine or ten hours.

Mr. Hodgman. We have cleaned the only force main in several cities, but I know of no place where the single force main cleaned was larger than 12-in. In cases of this sort we have a temporary make-up which we use to put the pipe in service. This temporary make-up can be put in in a very short time, and the water will pass through even when the machine is in the pipe, enough to give service in case of necessity. We have had only one experience where a fire broke out on the street where the main was being cleaned. That was on a 6-in. line in Warren, Pa. The main was cut in two places when the alarm was given, and eleven minutes thereafter there was pressure on the hydrants and no serious trouble resulted.

* Civil Engineer, National Water Main Cleaning Company.

Mr. Fuller. I should like to ask if it is necessary to shut off the main at the corporation cock or at the sidewalk?

Mr. Hodgman. In the house is as good as at the corporation.

Mr. Fuller. The rust does not get into the service pipe?

Mr. Hodgman. Even if it were not shut off at all, if the fixtures in the house were perfectly dead, there would be no trouble with stoppage.

Mr. Edwin C. Brooks. I will say that while I was at Cambridge we cleaned some 900 ft. of 6-in. pipe without taking any precautions about shutting off the supplies, or anything of the kind. The work was all done during the working day, and, although I had no means of determining what the increased flow was, still we found the discharge from the hydrants very perceptibly increased, and the job as a whole was very satisfactory.

Mr. Hodgman. We cleaned several miles of mains in Boston this spring, giving an increase of 210 per cent. on the 16-in. line on Brooks Street, East Boston, restoring the efficiency of that pipe to a coefficient of 139 by Williams and Hazen's formula. I would like to ask if Mr. Winslow can give some descriptions of our work.

Mr. Frederic I. Winslow.* I did not have charge of the work just referred to by Mr. Hodgman, but in 1885 and 1886 we cleaned a few 4- and 6-in. mains in East Boston and South Boston. We found, in one case, that with a flow of 100 gal. per minute, the friction per 1 000 ft. of 6-in. pipe was 25 ft. before, and but 4 ft. after, cleaning. In another case with 83 gal. per minute, the observed friction before cleaning was 12 ft. per 1 000 and after the cleaning it was but 2.5 ft. This work was all done with a machine made by D. H. Sweeney, of Fitchburg, Mass., and consisted of a flexible central shaft, composed of solid steel springs connecting small castings, to which were hinged steel scrapers arranged radially around the shaft. There were coiled springs which kept the scrapers against the sides of the pipe and yet allowed the scrapers to turn back so as to pass taps or other obstructions. Rubber pistons, fitting the pipe closely, were attached to the shaft behind the scrapers, and the machine,

*Engineer of Extension, Water Service, Public Works Department, Boston, Mass.

placed inside the pipe, was forced through by water pressure. These pipes were thirty years old and originally uncoated.

A MEMBER. I would like to ask what happens to the corporation cocks when they happen to protrude through the pipe.

MR. HODGMAN. There have been a number of cases where that question has come up and special examinations have been made, and although in some places a slight mark would show on the very point of the corporation where the machine had passed it, no damage was done whatsoever.

MR. WILLIAM F. CODD.* We have had some 4- and 6-in. pipes cleaned by this company in Nantucket, Mass., with very good results. The first 4-in. main we had cleaned was 1 000 ft. long, and had been in use about thirty years, and it was about half full of rust and sediment, so that from a hydrant on the middle of the main we could get a stream which would just barely flow out of the opening. After the cleaning was done we could get a good fire stream, sufficient for use on a two-story house. We were very well satisfied that there was nothing at all left in the interior of the pipe after the work was done, and no services were filled up, and no damage was done to the corporation cocks or anything else that I could see.

A MEMBER. How small a pipe can be cleaned with pressure where you do not have to use a cable?

MR. HODGMAN. That depends a good deal on what is in the pipe. We have cleaned some 4-in. pipe with pressure, where they had 100 lb. or better. Ordinarily we consider that nothing under 12-in. can be cleaned with pressure.

MR. FULLER. May I inquire how this cable is introduced to pull the machine along?

MR. HODGMAN. First the main is cut in two places; the riser pipe is put in position at the end where we expect the machine to come out, and we put our temporary connection in at the other end, putting first the double carrier cup and a small cable attached. Turning the pressure through the temporary make-up, it drives this small cable through. That is tied to the large cable and the large cable pulled back with a windlass. Then the machine is attached to the heavy cable and pulled into the pipe, the pipe is

* Treasurer and Superintendent, Wannacomet Water Company, Nantucket, Mass.

made up permanently at that point, and the water turned on and the machine pulled through, flushing simultaneously. We don't use any other but man power, because you really have to feel your way through. We wouldn't guarantee the corporation cocks at all if we used any power except hand power, because once in a while a blade will catch temporarily on the corporation cock, and then it is just pulled over carefully, because all the blades are spring blades and they may not spring back, if the machine is going too fast.

In connection with the cut shown in Mr. Saville's paper of the 20-in. machine used on the Hartford work I think it would be of interest to the Association to note that this is only one of nine different types of machines which are used in various kinds of work. I submit herewith a picture of our turbine machine which is used under certain conditions. This machine is entered through a hatch

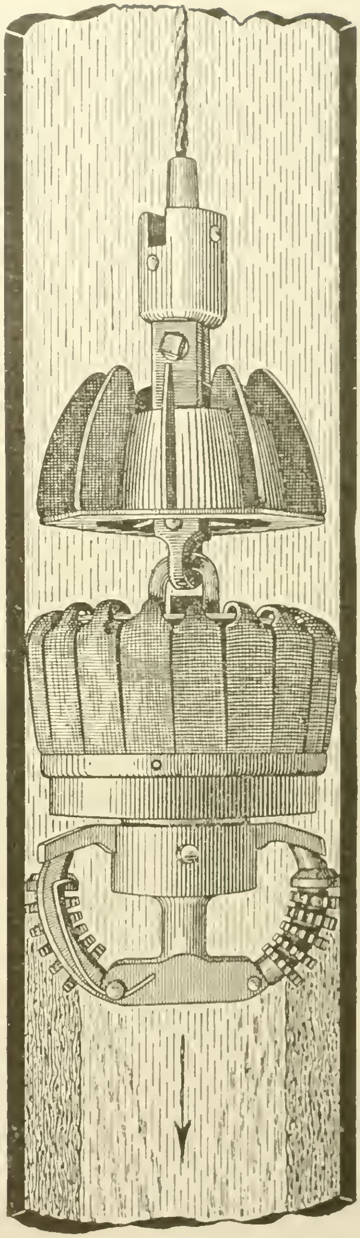


FIG. 4.
A TURBINE CLEANING MACHINE.

box at one end of the line and is held back so that the cutting head is free to act upon the incrustation.

As has been noted heretofore, there are also other types of machines which are drawn by cable, and many different types of blades which are used on these various machines.

LOSS OF HEAD IN BENDS.

BY W. E. FULLER.

[*Read September 11, 1913.*]

There has been much disagreement as to the loss of head due to bends or curves in pipe lines. Many theories have been advanced as to the cause of this loss, and many attempts to determine the laws which govern it have been made. Experiments made with great care by different experimenters have resulted in quite different conclusions. It is not the purpose of this paper to advance any new theory, nor has the writer any additional experimental data to offer. It is the object of this paper to put the reliable data on the subject in a form which can be readily used in determining the probable loss of head in bends and curves under the conditions that are ordinarily met with in water-works practice.

It may be well to state briefly some of the causes of loss of head in bends and the reasons why experiments have not given results similar in all cases.

It is known that water passing around curves and bends loses a greater amount of head than when passing through an equal length of straight pipe. When the direction of the flow of water is changed, the distribution of velocity and pressures in the pipe is also changed, eddies are set up, and probably other actions take place which cause this excess loss.

It is more convenient, in comparing different bends, to divide the total loss of head due to the bend into two parts: First, that which occurs in an equal length of straight pipe; second, the excess loss due to the curve. If this is done it is necessary to assume that the effect of roughness of pipe, condition of joints, and other matters which affect the flow in straight pipe have the same effect on the flow in curved pipes. Quite probably this is not exactly true, in which case bends of the same dimensions with different hydraulic conditions would give different excess losses of head. The experimental data are insufficient to decide this matter, but they indicate that the effect of roughness, etc.,

is not greatly different in the two cases. Loss of head due to bends will be considered as that portion of the total loss in excess of the loss which would occur in an equal length of straight pipe.

It is known that the disturbance caused by the bend is continued for some distance in the straight pipe beyond the bend and that the loss due to the bend continues in this straight pipe. It is also probable that the pipe preceding the bend, causing more or less eddies, according to its condition, may affect the loss due to the bend. The fact that some of the loss due to the bend takes place in the straight pipe makes it necessary in experimental work to measure the head at some distance beyond the bend itself. The loss due to pipe friction must then be eliminated before the loss due to the bend can be obtained. This pipe friction represents a large proportion of the total loss, so that errors in obtaining it materially affect the loss due to the curve. With all these difficulties to overcome it is not surprising that the different experiments should not agree closely.

MAIN POINTS AT ISSUE.

For practical purposes it is essential to know the effect of both the radius of the bend and the velocity upon the loss of head for pipes of different sizes.

Until recent years Weisbach's formula, based upon experiments made on small pipes, was generally accepted. This formula is:

$$h_b \text{ (additional loss of head due to } 90^\circ \text{ bend)} = 0.13 + 1.85 \left(\frac{D}{2r}\right)^{\frac{3}{2}} \left(\frac{v^2}{2g}\right),$$

in which D is diameter of pipe, r the radius of the center line of the bend, and v the average velocity in the pipe. On this basis the greatest loss of head would be from a bend of the smallest radius, and the longer the radius the less the loss would be.

Experiments by Williams, Hubbell, and Fenkell* at Detroit on pipes of 12, 16, and 30 in. in diameter, indicated losses quite different from those given by the Weisbach formula. From

* "Experiments at Detroit, Mich., on the Effect of Curvature upon the Flow of Water in Pipes," by Gardner S. Williams, M. Am. Soc. C. E.; Clarence W. Hubbell, M. Am. Soc. C. E., and George H. Fenkell, M. Am. Soc. C. E. Transactions Am. Soc. C. E., vol. 47. 30-in. pipe data, pp. 185 and 360; 16-in. pipe data, pp. 159 and 185; 12-in. pipe data, pp. 181 and 185.

these experiments it was concluded that the loss of head was a minimum for bends with radii of about two and one-half times the diameter of the pipe. These experiments also indicated that the loss did not in all cases vary as the square of the velocity.

Further experiments made by Schoder * at Cornell on 6-in. pipe, Davis† at the University of Wisconsin on 2-in. pipe, Brightmore ‡ in England on 3-in. and 4-in. pipe, and others, showed that the Weisbach formula did not hold for larger pipes under ordinary conditions of service. These later experiments, however, did not confirm the Detroit experiments as to the minimum loss occurring with bends of a radius of $2\frac{1}{2}$ pipe diameters. These different experiments indicated quite different variations of loss in relation to the velocity. Some of the experiments showed this relation as high as $v^{2.75}$, while others showed it as low as $v^{1.5}$.

These experiments give the best basis that we have of obtaining the loss of head in bends.

The experiments were all carefully made, every effort being made to eliminate errors. The conditions existing for the different experiments were near enough alike to justify the expectation of at least an approximate agreement.

In the discussion of the question resulting from these experiments it seems to have been assumed that the loss of head in bends on different sizes of pipe should be the same when the radius of the bend in terms of the diameter of the pipe were alike. The writer sees no valid reason why this should be so. With so many different factors contributing to the loss there seems no reason to assume such a relation. If this assumption is abandoned, a much closer agreement between the data can be obtained and it seems better to accept the experiments as they stand, adjusting the conclusions to the data rather than to assume that some of the data are in error simply because they do not satisfy the above assumption.

* "Curve Resistance in Water Pipes," by Ernest W. Schoder, Assoc. M., Am. Soc. C. E., Transactions M. Am. Soc. C. E., vol. 62.

† Discussion of "Curve Resistance in Water Pipes," by George J. Davis, Jr., Assoc. M., Am. Soc. C. E. Transactions Am. Soc. C. E., vol. 62, page 103.

‡ "Loss of Pressure in Water Flowing through Straight and Curved Pipes," by A. W. Brightmore, M. Inst. C. E. Minutes of Proceedings Inst. C. E., vol. 169, p. 323.

EFFECT OF THE RADIUS.

A study of the data shows that the loss is more nearly the same for different sizes of pipes with bends of the same actual radius in feet than for bends of the same radius in pipe diameters. This is shown by a comparison of Figures 1 and 2.

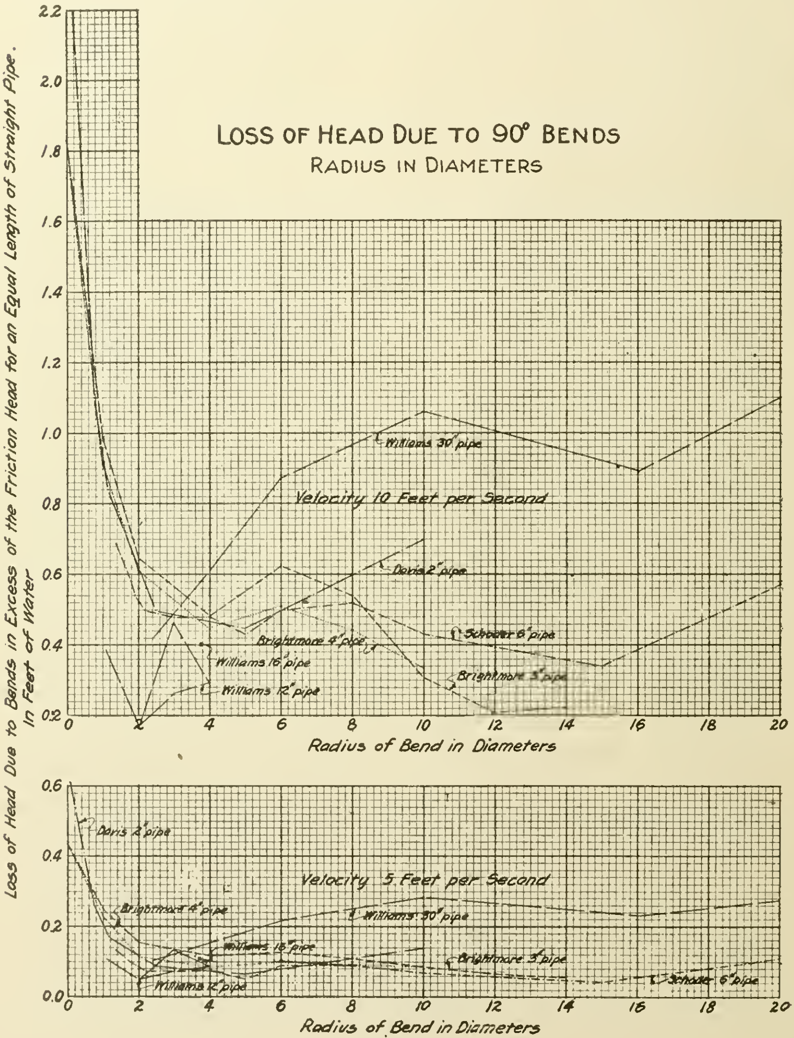


FIG. 1.

Fig. 1 shows a plotting of the data on the basis of the radius in pipe diameters, while Fig. 2 shows a similar plotting on the basis of the radius in feet. On Fig. 1, while the curves representing the losses in bends of diameters from 2 in. to 6 in. agree fairly

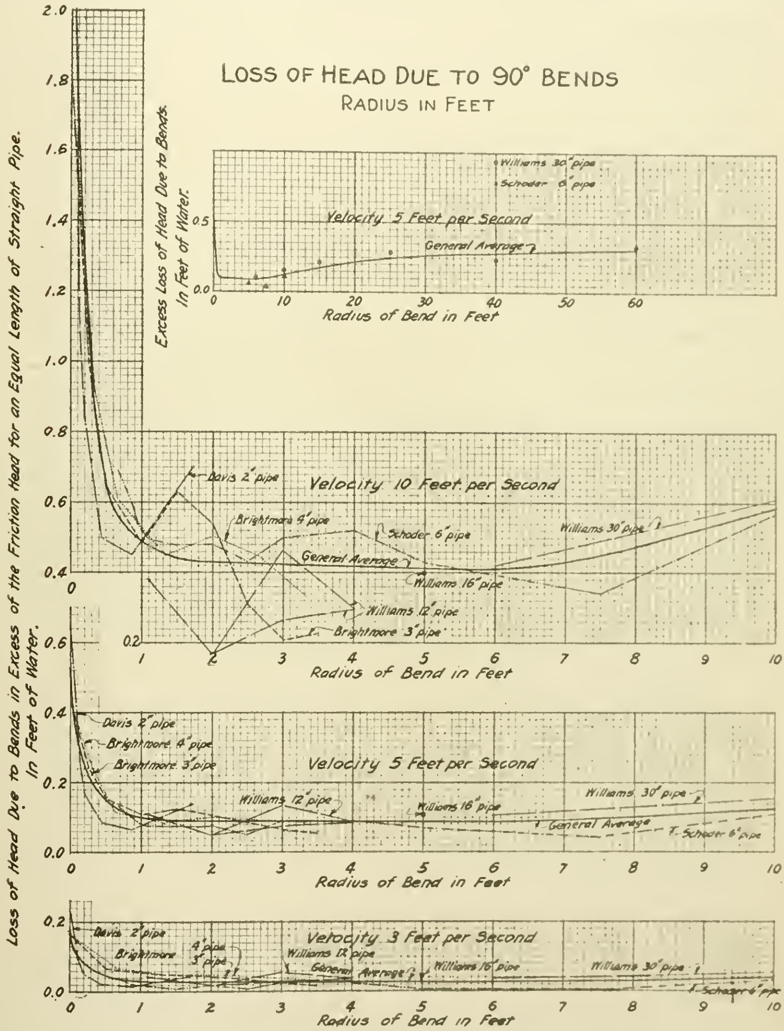


Fig. 2.

closely, those for the larger pipes are very different. On Fig. 2 a much closer agreement between the small and large pipe curves is obtained.

It is probable that neither of these diagrams is on the correct basis, and that the actual relation between the loss of head and the radius is a more involved one. Possibly the inner radius or the outer radius of the bend should be used for the comparison instead of the radius of the center line; or it may be that both r and D are involved in some more complicated form.

On Fig. 2 the average curves drawn fit the data approximately, and may be used for obtaining the probable loss of head in bends.

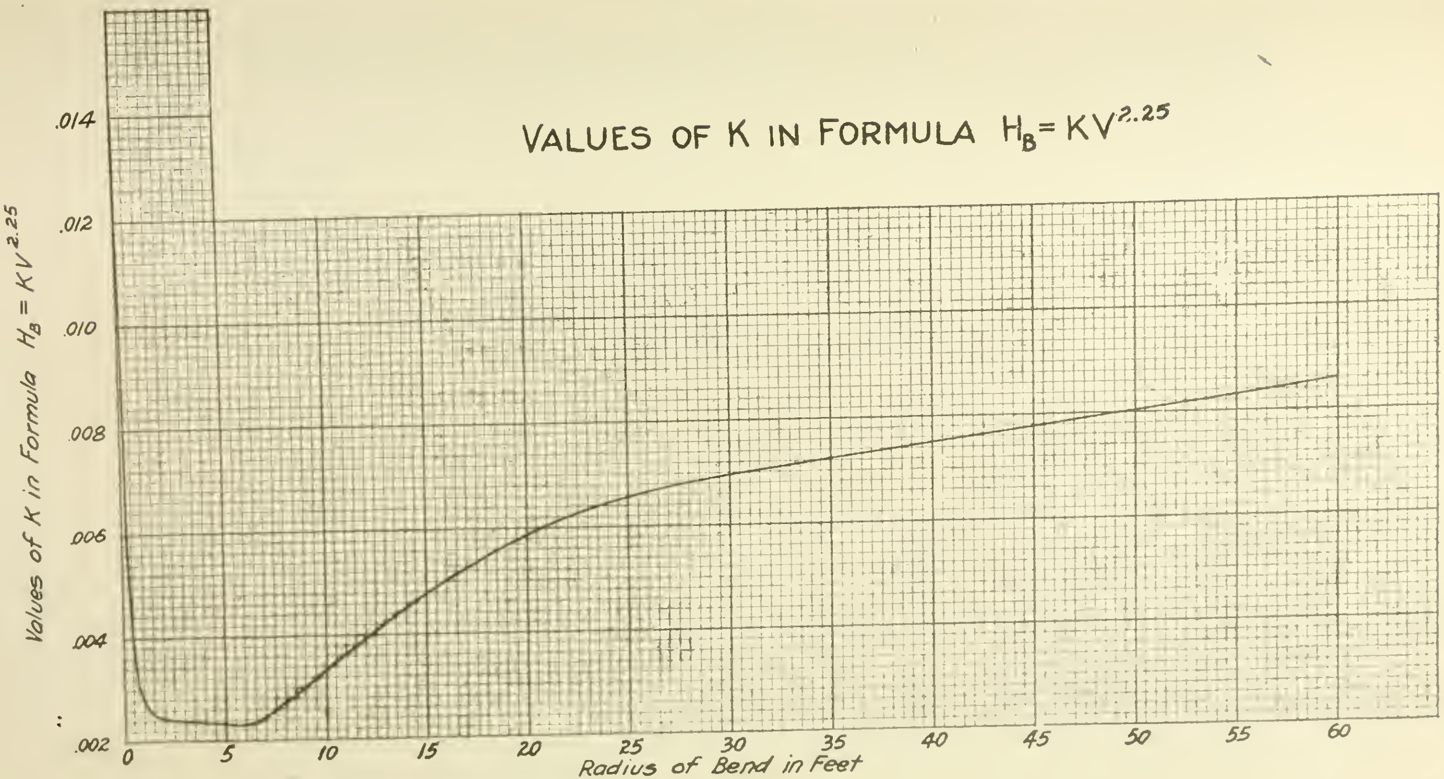
RELATION OF LOSS OF HEAD TO VELOCITY.

Values of the loss of head for different velocities due to bends of the same radius, taken from the average curves on Fig. 2, were plotted on logarithmic paper in relation to velocity. From these plottings the relation was established that the loss of head is proportional to $v^{2.25}$. On this basis a formula for loss of head may be stated as $h_b = kv^{2.25}$, in which k is a coefficient different for bends of different radii, and h_b is the loss of head in excess of the loss in a straight pipe of a length equal to the length of the curve. On Fig. 3 is given the values of k for bends of radii up to 60 ft. This relation between h_b and v is an average relation, as indicated by the experiments used. Further experiments may change it materially.

PRACTICAL USE OF THE DATA.

Fig. 2 gives the loss of head due to 90 degree bends in excess of the loss due to friction in straight pipe of a length equal to the length of the curve. To compare the total loss of head which would actually occur in pipe lines containing these curves, it is necessary to take into account the relative length of the different curves. The use of long curves makes the total length of pipe less than the use of short curves giving a corresponding smaller loss in pipe friction.

The introduction of this matter brings in a difficulty in that the friction will vary as the roughness of the pipe, so that the curve giving the least total resistance for one pipe will not do so for an-



VALUES OF K IN FORMULA $H_B = KV^{2.25}$
.014
.012
.010
.008
.006
.004
.002
Values of K in Formula $H_B = KV^{2.25}$
0
5
10
15
20
25
30
35
40
45
50
55
60
Radius of Bend in Feet

FIG. 3.

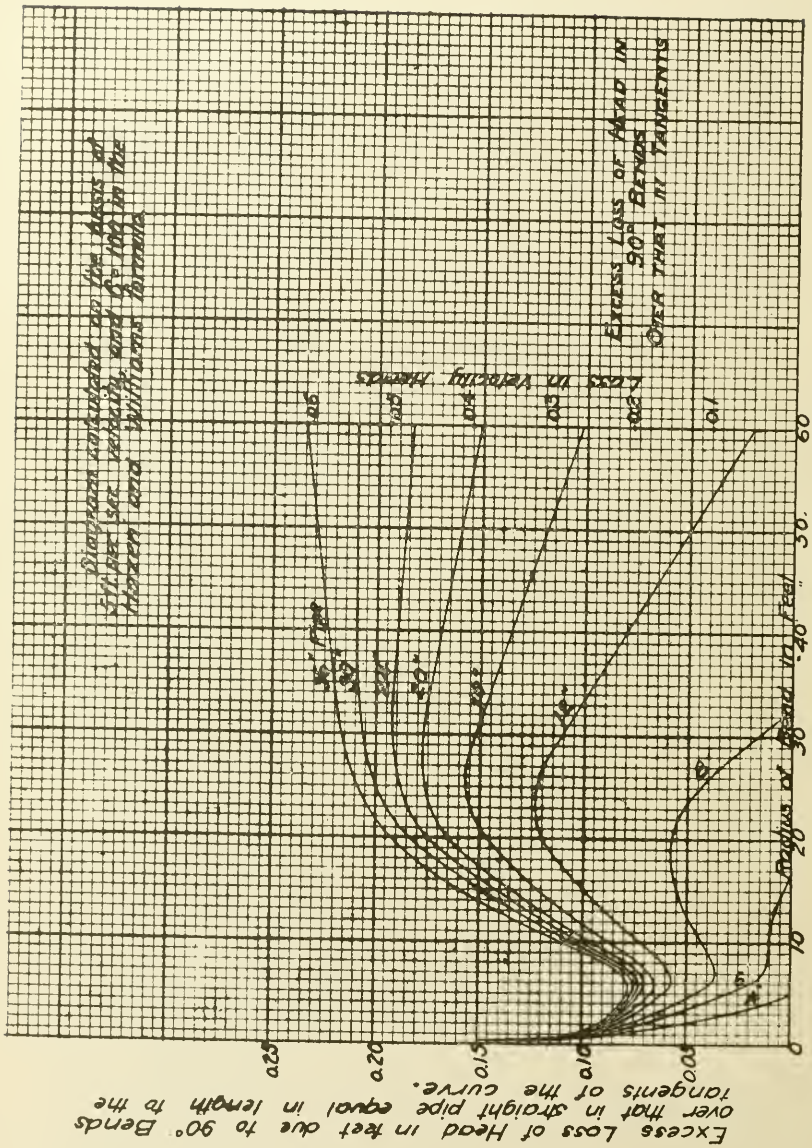

Excess Loss of Head in 90° Bends
Over that in Tangents
Loss in Velocity Heads
Radius of Bend in Feet
Excess Loss of Head in feet due to 90° Bends over that in straight pipe equal in length to the tangents of the curve.

Fig. 4.

other pipe with different hydraulic conditions. It is most convenient to compute the loss of head in pipe lines by taking the actual lengths of the tangents as straight pipe, finding the frictional resistance in it, and then adding the excess resistance due to curves and other specials.

To meet this requirement Fig. 4 has been drawn, on which is shown the excess loss of head in bends over what would occur in straight pipe of a length equal to the tangents of the curve under average conditions. The data for plotting this diagram were obtained as follows: The loss due to the curve is taken from the average curve in Fig. 2. The friction in straight pipe of a length equal to the difference between the length of the tangents and the length of the curve is then deducted. The frictional resistance in straight pipe is taken according to the Hazen-Williams formula with $c = 100$. This coefficient represents the average pipe after it has been in use for some years. As the loss of head in bends becomes of most importance at the time when the pipe is being used at its maximum capacity, which usually comes after some years of use, this value of c will probably meet the usual requirements. For new pipe well laid this excess loss in head would be somewhat greater, while for pipe in very bad condition it would be less.

Fig. 4 shows the following interesting points:

1. The excess loss of head in bends is greater for large pipes than for small ones.

2. For large pipes a six-foot radius bend gives the least resistance, unless very long radii are used.

3. If the radius can be made very long, the least resistance will evidently be from the bend of greatest radius.

4. For small pipes, at least, with long radii the loss of head will be less than it would be in straight pipe of a length equal to the tangents of the curve. This occurs when the saving in friction head due to shorter line becomes greater than the excess loss due to the bend.

NEW ENGLAND WATER WORKS ASSOCIATION STANDARD BENDS.

In order to show the loss of head for bends in ordinary use, Table 1 has been prepared on the same basis as Fig. 4, giving

the excess loss for bends made according to the New England Water Works Association standard.

TABLE I.

LOSS OF HEAD DUE TO NINETY DEGREE BENDS OF THE NEW ENGLAND WATER WORKS ASSOCIATION STANDARD.

Size of Pipe. Inches.	Radius Bend. Feet.	Excess Loss over Loss in Straight Pipe of Length Equal to Tangents. v=3 ft.	v=5 ft.	v=10 ft.
4	1.33	0.021	0.073	0.37
6	1.33	0.025	0.082	0.40
8	1.33	0.026	0.086	0.41
10	1.33	0.027	0.089	0.42
12	1.33	0.028	0.090	0.43
16	2.0	0.026	0.085	0.41
20	2.0	0.027	0.086	0.41
24	2.5	0.026	0.085	0.41
30	3.0	0.026	0.083	0.41
36	4.0	0.026	0.083	0.40

NECESSITY FOR CONSIDERING LOSS IN BENDS.

For most lines of small pipe, consideration of economy or convenience in laying will govern the selection of the bend or curve to use. Generally, of course, the use of very sharp bends should be avoided. In designing pipe systems about pumping stations, filter plants, and elsewhere, where many specials are necessary, a thorough understanding of the loss is important to avoid unnecessary loss of head.

For large pipes the losses in bends assume a far greater importance. The loss is more important for several reasons. First, the actual loss is greater for the larger pipes than for small pipes. Second, for the same velocity the frictional loss is less for large pipe than for small pipe, so that the loss in bends is a greater proportion of the total loss. Third, the amount of money involved is greater in the case of large pipe, and a greater expenditure is justified to avoid losses of head.

The importance of losses of head which occur on large pipe lines at bends and at other specials and at entrances and outlets of the pipe to structures is not as generally realized as it should be.

It is not uncommon to find losses from such causes, in large and comparatively short pipe lines, a large percentage of the total loss. In many cases much greater capacity of the line could have been obtained by proper consideration of the losses in the design of these works, and in some cases the capacity could have been nearly if not quite doubled. Instances of this may be found in intake and suction pipes. The importance of these losses may be understood when it is realized that in 1 000 ft. of 72-in. pipe a single 90 degree bend poorly designed may readily reduce the capacity of the line by 5 per cent., and a poorly designed inlet or outlet of the pipe to a structure may reduce the capacity by fully 10 per cent. It is not uncommon to find structures on pipe lines in which the velocity is suddenly reduced to a small amount, after which it is again increased. Such structures are extremely wasteful in head. A careful design to secure gradual changes in velocity and to prevent eddies at specials is very essential in order to secure the proper capacity of large lines and to prevent the waste of capital in building larger pipe lines than are needed.

LOSS OF HEAD IN OTHER THAN NINETY DEGREE BENDS.

There are but little data on losses in curves of radii other than 90 degree curves. Even with bends of small curvature the flow is disturbed, eddies are started, and considerable loss of head may result. It seems certain that the loss in 45 degree bends is greater than one half that in 90 degree bends. Until more information is obtained, the writer suggests the use of the following values for losses of head:

For loss of head due to 45 degree bends, use three fourths that due to 90 degree bends of the same radius.

For loss of head due to 22.5 degree bends, use one half that due to 90 degree bends of the same radius.

For loss of head due to a Y-branch, use three fourths that due to a tee.

APPROXIMATE RULES FOR LOSSES OF HEAD.

The loss of head in bends, for ordinary velocities, that is, from 3 to 6 ft., is approximately proportional to the velocity head $\left(\frac{v^2}{2g}\right)$.

It is convenient to express the loss in this way, and for rough approximations the following rules will serve.

For 90 degree bends of a radius in excess of 1.5 ft. and less than 10 ft., $h_b = \frac{1}{4}\left(\frac{v^2}{2g}\right)$.

For tees (bends of zero radii), $h_b = 1\frac{1}{4}\left(\frac{v^2}{2g}\right)$.

For sharp 90 degree bends of 6-in. radii, $h_b = \frac{1}{2}\left(\frac{v^2}{2g}\right)$.

Only further experimental work can satisfactorily settle some points involved in the loss of head in bends. Experiments which would add to the data on the loss of head in bends of large diameter would prove of the greatest service. It is for such bends that the matter is of the greater importance and the data more limited.

DISCUSSION.

Mr. Francis T. Kemble. Mr. President, I would like to ask Mr. Fuller whether his experiments cover differences of speed. With a railway curve it is considered that different curves have different speeds; you will run round a given radius with less friction at 30 miles an hour than you will at 40 or 50 miles an hour.

Mr. Fuller. The data indicate that the radius of the bend of least resistance for one velocity would not be the same as that for another velocity. This difference, however, is slight, and the data which we have are probably not sufficient for such refinement. Fig. 3 gives the value of K in the formula $H_b = KV^{2.25}$. By the use of this formula the loss of head for any velocity may be obtained.

Mr. Allen Hazen. Mr. President, this is certainly a most important subject. I think the matter of extra loss of head in bends and special structures and entrances is one which baffles engineers and those who make hydraulic calculations more often than any other. More disappointment in the expected capacity of pipes has come from inadequate allowances of this kind than from any other single cause. I have known repeatedly of cases where pipes have been installed to deliver certain quantities of

water, and have failed to come up to expectations because adequate allowances were not made for these extra losses. Mr. Fuller's study bears out the general idea which we have had for many years, that a fair allowance for ordinary bends in water-works practice is about a quarter of a velocity head; but it shows that we shall have to be more careful in applying this rule to see that the curves come within the limits to which it applies.

Mr. Richard Winslow Sherman. In view of the well-known fact that friction is largely caused by the confusion of the particles of water in flowing through a pipe, this confusion being much increased in passing round bends, this increase, according to the author, having some relation to the length of the bend, would it be a fact that in a 24-in. pipe making a right angle bend with a radius of 5 ft., the loss of head by friction would be less than if the same bend were made with a radius of 15 ft., by reason of the confusion of the particles of water in the pipe occurring throughout a greater length of bend, say, three times as much length with a 15-ft. radius as with a 5-ft. radius? Would that be the case, would the loss be less in the shorter bend?

Mr. Fuller. For the 24-in. pipe there will be more total loss of head in a pipe line with the use of a 15-ft. radius bend than with a 5-ft. radius bend. With 6-in. pipe or smaller this would not be true; and with the 24-in. pipe, if the radius were made very long, perhaps several hundred feet, the loss would be less than with a 5-ft. radius.

ADVISABILITY OF SECURING LEGISLATION FOR MAKING WATER BILLS A LIEN UPON PROPERTY SUPPLIED.

TOPICAL DISCUSSION.

[*November 12, 1913.*]

Mr. Robert J. Thomas.* In regard to making water bills a lien on property, some years ago, as president of the New England Water Works Association, I signed a petition to the Massachusetts legislature to have a law to that effect enacted, and with a number of other water-works men of Massachusetts appeared before, I believe, the Committee on Cities and advocated a law to that effect. The city of Boston was represented by its water commissioner and by its attorney, and several other cities were represented.

There was no question about the arguments being to the point, and there was no question but that we were successful in presenting clearly to the committee that such a law should be enacted; that under the present conditions several water-works departments had lost thousands of dollars each year, because of the fact that they were unable to collect the water bills on property that had been transferred from one owner to another.

In the years when water bills were based upon fixtures, and were rendered a year in advance, it was an easy matter if a bill wasn't paid within a month or two to shut off the water or to collect the bill before the water was shut off. But when meters came into use, and it became necessary to have the water supplied for three months or four months before a bill could be rendered, then a city or town was liable to lose the water bills for those three or four months before the water could be shut off, as the bills were not rendered until a month after a quarter during which water had been supplied. So that the advent of meters made it necessary that some law should be passed to enable water departments to collect the money due them for the three months previous.

* Superintendent of Water Works, Lowell, Mass.

The city of Boston, if I remember rightly, their commissioner stated, had lost something like thirty thousand dollars a year from delinquent water takers. The city of Worcester had lost several thousand dollars a year from the failure to collect water bills, owing to change in the ownership of property. A law was passed in 1898 which prevented any water department from shutting off the water due to a bill contracted by a previous owner. That caused a hardship to the water departments, and prevented them from collecting many bills that were due.

To any person familiar with the subject, or any disinterested party listening at the hearing before the committee, there could not have been any doubt that the case had been presented successfully, and that the committee ought to have reported a law making water bills a lien on property. There was no opposition, no remonstrance whatever. No member of the committee disputed any argument that was made there, nor any assertion. In consequence we naturally thought that an act would be passed in accordance with our petition.

Shortly after the hearing before the committee, I met what is called a "legislative agent" in the lobby of the State House, and talked the matter over with him. I told him that there had been no opposition to the measure and that we were very hopeful of getting it through. He looked very surprised to think that I was so simple-minded as to expect that a bill like that would go through, notwithstanding the fact that there was no opposition. "Why," he said, "there won't be a member of that committee who will favor the bill." I said, "There was no opposition to it at all." He replied, "They don't have to go to meetings of the committee to oppose anything of this kind; it will be done quietly, and the committee will report against the bill." And they did, and the bill failed of passage. Although there was a strenuous fight made on the floor of the House, a majority voted to accept the report of the committee.

I understand the point they made was that it was up to the cities to collect their own bills by shutting off the water, to look after their bills more closely, not to allow the bills to be outstanding so long, and that within thirty days, anyway, of the time a bill was rendered the water should be shut off or the bill paid, and if it

wasn't it was the fault of the water department or the city or the collectors of the water bills in the different cities, and we had no business to come to the legislature and expect any assistance from them. I have considerable doubt as to whether any other attempt would be successful in getting such a bill through. Of course there is nothing like trying.

MR. A. R. HATHAWAY.* If the "lobby argument" was sufficient to block such legislation in enlightened Massachusetts I would like to ask, what was the argument successfully used in New York State, in the state of Connecticut, and in other states we might mention, which have had such a lien law for a number of years, and what was the argument so successfully used in San Diego, Cal., which has put in a large water system recently and has adopted new and up-to-date ordinances, rules, and regulations, among them being the following very drastic lien-law?

ABSTRACT FROM NEW ORDINANCES GOVERNING WATER WORKS AT SAN DIEGO, CAL.†

"*Penalties for Delinquents.*

"Should an account not be paid within ten days after coming due, a penalty of 10 per cent. shall be added to the bill, and if the total amount then due is not paid within ten days after the adding of the penalty, the said account and penalty shall be deemed delinquent and an additional penalty of 50 cents shall be added, and the superintendent of the Department of Water may cause the water to be shut off from the premises from which the account is delinquent, and the water shall not again be turned on until all arrearages and charges shall have been paid."

"*Rates Lien against Property.*

"In addition to any other remedy provided herein for the enforcement and collection of any water rate, charge, or account, all rates provided for in this ordinance shall be charged against the property on which it is furnished, and against the owner thereof, and shall be a lien against the premises to which any water may be supplied, and a charge against the owner thereof and the occupant thereof using the water, and if for any cause any sums owing therefor become delinquent, the water shall be shut off, and in no case shall it be turned on to the same property until all such delinquencies shall have been paid in full and such property

* Water Registrar, Springfield, Mass.

† Copied from *Engineering News*, September 4, 1913.

owner and occupant shall be severally responsible to the city in an action waged by the city in any court of competent jurisdiction for the amount of all such rates as may be due and unpaid, together with all penalties provided herein and costs. No change of ownership or occupation shall affect the application of this section."

I am deeply interested in this question, and I wish there could be a water lien-law passed which would help us in collecting our bills for metered supplies. I believe that the amount of money any city loses is not the main argument, — I know in Springfield we collect very closely, — but there is a growing tendency among new owners of property to avoid payment of water bills left against the property acquired. I believe that this Association ought to look into this matter more than it has, and, perhaps, stand by another movement for a lien-law.

Mr. George A. King.* Last winter Mayor Fitzgerald petitioned the legislature for an act of this kind, and the corporation counsel, Judge Corbett, appeared in the interest of the city of Boston and advocated before the Committee on Judiciary the enactment of such a law. I was there, and as there was no one there to object, I used the name of the New England Water Works Association and the water departments of Massachusetts as freely as I could. There was no opposition at the meeting, no one spoke against the proposition; there were two in favor and no one against. The committee reported reference to the next General Court.

I think the opposition comes from the real estate men. They object to having an additional burden put upon conveyancing, and they employ the legislative agents. I would like to ask Mr. Ballou of Woonsocket how the law which was enacted in Rhode Island some five years ago is working.

Mr. Arthur F. Ballou.† There is a law in Rhode Island that a water bill is a lien on property. If the ownership changes and there is an unpaid water bill, we shut off the water, and if the new owner wants water the only way he can get it is by paying the bill. We don't have any unpaid bills. But the law has never been tested, and I think that if anybody with

* Superintendent Water Works, Taunton, Mass

† Superintendent, Water Works, Woonsocket, Mass.

sufficient financial backing were to take the matter into court he would win. The law works all right however, so long as it is uncontested, so we are quite content with it as it stands.

Mr. Lewis M. Bancroft.* The gentleman says that the water remains shut off until the new owner asks to have it turned on; but how does the department find out that the property has been sold? I know that in our town many times property is sold and, perhaps, it is several months before we find out who the new owner is. I had one experience which was rather amusing. I telephoned to the man who was the former owner of the property and asked him who the new purchaser was, and he replied, "It is up to you to find out."

I have attended several hearings at the State House before the Judiciary Committee and the Committee on Cities, of which Mr. Thomas has spoken, and one objection which I heard raised at one of the hearings was made by a conveyancer, who made the claim that it would make one more thing for him to look up, and would cause him a little trouble.

Mr. Hathaway. I have heard that objection also, but at home I have talked with several of our leading lawyers, among them one who is perhaps one of the leading conveyancers in the state, and he has always maintained that there is no legal objection, and no vital objection, that he could see, to making water bills a lien on the property. I have talked with real estate men, and you know how they can raise objections from their own point of view. They don't want the bother of going to the place of record, or of including the water bill in their transactions, in the dickering about a piece of real estate; but it can, of course, be done, and theirs are simply selfish objections, when you simmer them down. I was speaking only yesterday with our city collector, and he was emphatic in saying the water bills ought to be a lien on the premises, so that cities and towns should be assured of their revenue. It seems to me that the principle of the thing is right, and I can't see any good objection to it. I was talking with a real estate man day before yesterday, — a man who has acquired considerable real estate under foreclosure and by watching for bargains — and one who would naturally be expected to make

* Superintendent Water Works, Reading, Mass.

objection to having the water bill a lien on the property, — and he said: "Of course it will make another thing to take into account. When I buy a piece of property under foreclosure I expect to pay the insurance, the taxes, and other municipal assessments, and if the water bill was a lien on the property I should expect to pay that also. But after all," he said, "I really can have no vital objection, as in the end it all comes out of the tenants."

Mr. Frank L. Fuller.* It seems to me that if we make the owner responsible for the water bill the tenant will have no incentive to use a moderate amount. If the tenant intends to go out and not pay his water bill, he cares nothing about how much water he uses. In such places, where the landlord pays the water rate, the tenant has no pecuniary incentive to use only a reasonable amount. It seems to me, looking at the matter from this standpoint, that the proposed lien-law is not a good one. I don't know how it is in large cities, but in a town like Wellesley we have comparatively little trouble in collecting our water bills from tenants. There are a great many tenants, and the water is charged directly to them, and we lose very little money from them.

An advance charge should always be made to cover loss from a shifting population.

Mr. John O. Hall.† This is a question of a great deal of importance, and it has many phases. As I understand the situation at the present time, the bill has been referred to the next General Court. Now, I would suggest two things: First, that the committee having this matter in charge see that the bill is resurrected and put in the calendar in January for action; and, second, that the present committee, or a subcommittee, appear before the Massachusetts Real Estate Exchange and advocate the matter in its various phases before them, and get a number of them, as you undoubtedly can, to join with you in following up the bill and securing its passage. Then, when the bill has come before the legislative committee, the members of the Association should follow it up by conferring with their Representatives and Senators and securing the influence which they have on the floor of the Senate and House, in order to accomplish

* Civil Engineer, Boston, Mass.
† Quincy, Mass.

the desired result. That has been my experience and my method of procedure in various matters in which I have been interested in the legislature of Massachusetts. It seems to me that persistent work of that kind will finally result in securing what we all so earnestly desire.

Mr. Frank A. McInnes.* I will say that the corporation counsel of Boston proposes to again try to secure the passage of such a law. He requests, and would very greatly appreciate, the coöperation of the Association.

I think the last speaker has put the matter exactly right; we must meet our opponents in their own way. We must get the real estate men; they will not object, the best of them at least, and the lawyers, I think, will generally support us, as the legislation we desire is a necessity in the larger cities at least. Perhaps the gentleman from Wellesley does not need it as acutely as we do. Within a few years, we will have in Boston 100 000 meters; our bills are rendered quarterly, and it is fully two months after the bill issues, as our machinery operates, — we hope to expedite it, — before we can really get to the point of shutting the water off if the money is not forthcoming; this leaves a large loophole.

In the cities a class of people exists who apparently live to beat the water departments, and their method of transferring property is remarkable; last year we had about 12 000 transfers of property. The amount of money lost directly through unpaid bills is insignificant compared with the large additional cost of shutting off water, doing the extra clerical work and watching the thieves, — for that is what they are. The reputable people do not bother us; it is the disreputable ones. Something must be done, and I desire you to know that Boston proposes to bring the matter up again.

I want to repeat that Mr. Hall looks at the matter in the right way; in addition to stating what is right, and having everybody agree to do it, as has been done, we must take off our coats, go to work, and get results.

Mr. Albert L. Sawyer.† I can't see any reason why the water bill should not be a lien on property, the same as the sewer

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* Division Engineer, Public Works Department, Boston, Mass.

† Water Registrar, Haverhill, Mass.

assessment or taxes. In the city of Haverhill our losses on this account are reduced to a minimum, for the reason that out of our 1 700 meters, over one half are house meters, and for those we collect yearly in advance, at the beginning of the year, so that we really run small risk. As we also give 25 per cent. discount on the water bill, this in effect collects about 95 per cent. of the bills when they are due. I should like to see another bill of this kind introduced in the legislature, and then have the members of the Association back it up as well as they did the last time. It seems to me that if a bill is introduced we might get the aid of our legal representatives, and perhaps do something to offset this lobby on the other side, and so we might get it passed. Last year such a bill was advocated by Mayor Fitzgerald, and I think that if we can get the Democrats of Boston to favor a bill we might be able to get it through.

Mr. Percy R. Sanders.* We have had about the same success in New Hampshire that Mr. Thomas had with the Massachusetts legislature. In the session of 1910 a bill was introduced similar to the one that Mr. Thomas introduced in the Massachusetts legislature. We felt that with the increase of our meters, where the rates were collectible at the expiration of the quarter, we should be able to collect the bill from the last owner. In several instances we have collected the bill from the owner where the property has changed hands during the quarter. In one case he made objections and said he didn't believe we could collect it if it came to court, and it struck us that it might be true, although we didn't tell him so. One of the members of our water board was a member of the legislature of 1910, and he introduced this bill. It was referred to the Judiciary Committee, a day was set for the hearing, and a number of us appeared before the committee and advanced all the arguments we could in favor of the bill. The arguments against the bill were substantially as the gentleman from Boston says, — that it would make trouble for the real estate dealers and the lawyers to look out for more liens. The bill was returned from the Judiciary Committee to the House with the report "Inexpedient to legislate," and that is where the matter stands now. We collect our bills the same as we did

* Superintendent Water Works, Concord, N. H.

before — that is, we take advantage of the doubt and make the owners think we can do it.

Mr. Hall. Mr. President, I want to offer just one more suggestion. I was interested in the bill relating to municipal finance, which passed the legislature last year. I carried that matter before three legislatures before I got the bill passed. Before the bill was assigned I had prepared some one hundred and fifty postal cards, leaving a blank for the committee to which it would be assigned and for the date of the hearing; and I would make the suggestion that, if this matter is coming up, the committee in charge should make that preparation, and then should mail a notice to such members of the Association as they consider would be forceful in presenting the matter to the legislature, and in that way carry up 75 or 100 or 150 men, for a multitude counts, without any question, in a matter of this kind.

Mr. King. Mr. President, I move that a committee of five be appointed by the Executive Committee to take all necessary and desirable means to secure the passage of a statute in Massachusetts making water bills a lien upon real estate.

Vice-President Sullivan. I should think that the committee might be of some help in other states. I see that Mr. Sanders is looking this way. Is there anything to be said on the motion?

Mr. Martin. Would a suggestion that Mr. Hall be chairman of that committee be in order? He seems to have had a lot of experience.

Vice-President Sullivan. I dare say that the Executive Committee will take that suggestion into consideration, or you might offer it as an amendment to the motion.

Mr. Martin. I will move that as an amendment.

Mr. King. I will accept the amendment.

(The motion is adopted.)*

A Member. I would ask if you have any idea how private companies would be affected by any such legislation.

Mr. King. If I recollect the Rhode Island law, it did not act in favor of private water companies, and they were intending to see if they could secure an extension of the law, that is, to have an amendment made which would include them.

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* For the appointment of the Committee see page 553.

Mr. Hall. If I can serve the Association in this capacity, I shall only be too glad to do it, and I will give you the benefit of my municipal and legislative experience freely.

SMALL WATER PURIFICATION PLANTS. A PLEA FOR THEIR MORE EFFICIENT OPERATION.

BY H. P. LETTON, SANITARY ENGINEER, U. S. PUBLIC-HEALTH SERVICE.

[*Read December 10, 1913.*]

Several interesting papers have recently appeared dealing with the operation of sewage disposal plants and emphasizing the necessity for more careful supervision of this kind of municipal work. It is well known to all who have investigated the matter that small sewage disposal plants receive as a rule little or no attention, and that their effluents could be greatly improved under proper operation. Discussion of these matters is therefore advantageous and desirable.

The writer was for some time previous to last July in the employ of the New Jersey State Board of Health, engaged mainly in the supervision of the public water supplies of the state. In connection with this work about thirty water purification plants have been visited upon numerous occasions. As a result of these visits, it became evident that the opinions that had been expressed in regard to the operation of sewage disposal plants were largely applicable to small water purification plants.

The main difference in the two cases is this: Sewage disposal plants are usually built not because there is a concerted public demand for them, but for the eradication of a local nuisance, or by order of some higher authority. Because of this fact, and because the terms "sewage" and "sewage disposal" are distasteful to the average layman, the plant is generally put in an out-of-the-way place, and either forgotten entirely or placed in the charge of an underpaid, superannuated caretaker who knows nothing of the principles upon which the design of the plant is based; while a water purification plant is generally installed as a result of a popular demand and the consumer is directly interested in its operation in so far as furnishing a clear, colorless, and palatable water is concerned. These are the qualities that to the majority of people determine the purity of the water, and as long as

they are maintained there is little or no question as to the efficiency of the plant in other ways. As a matter of fact, however, there are many plants which will usually meet the above conditions but which are inefficient both from an economic and a sanitary standpoint.

It is only on rare occasions that a filtration plant has been constructed at the time of the installation of the water-works system. In most cases, when the purification plant is added to an existing system, the operation of it is intrusted to the engineer of the old plant. This man may be, and in many cases is, a stationary engineer who thoroughly understands the operation of boilers, engines, and pumps, but who has absolutely no idea of the principles which underlie the process of water purification.

There is also another point which in many cases affects the results obtained. When it is decided that some form of purification 's advisable in connection wi h a small water plant, it is very rare indeed that a consulting engineer is called in for advice. Instead, the matter is taken up with one or more companies engaged in the business of installing purification apparatus. While these companies are usually competent to give reliable advice, their main business is the selling of equipment. Because of this fact and because the usual small water company or municipality is weak financially, the filter plant is designed to fit the available money, and the company offering the equipment for the least sum is generally given the contract regardless of the quality of the material to be furnished. As a result of this practice, plants that are poorly designed, lacking in the necessary equipment for efficiency, or even wholly ill-adapted to the situation, are commonly met with. A few cases of this kind which have come under the observation of the writer will be noted. Probably the worst example was at a plant supplying about a million gallons per day. The supply was originally obtained from artesian wells, but on account of the high iron content of the water, a new supply was obtained from an artificial lake. This water was highly colored by its passage through cedar swamps. From the lake the water flowed by gravity to the coagulation basin. This was a rectangular wooden tank of such size that normally less than twenty minutes were allowed for coagulation and sedimentation. During

periods of high consumption the time was considerably decreased. The basin was set at such an elevation that at times of low water in the lake it was impossible to obtain the normal supply except by by-passing some raw water. From the coagulation basin the water flowed by gravity to four rapid sand filters of the gravity, circular wooden tank type, without loss of head gages or rate controllers. The agitating rakes were intended to be driven by a water motor, but the necessary power was lacking. The beds were therefore not agitated during washing. From the filters the water passed to a suction well which had been used in connection with the former well supply, and which provided less than thirty minutes' storage. Two solution tanks had been provided and connected with a small displacement pump driven from the line shaft to which the main water pumps were attached. The small solution pump was intended to force a solution of sulphate of alumina into the raw water just before it entered the coagulation basin. At the time of the writer's first visit to this plant the chemical pump was out of order and no chemical was being added. It was afterward learned that this was its chronic condition. Tests of the raw water showed it to be slightly acid owing probably to humic acid from the cedar swamps. Consequently the addition of sulphate of alumina would be an absolute loss as far as results are concerned. Analyses of the raw and filtered water showed no material difference, and the filtered water had at times a color as high as two hundred.

While the foregoing may seem to be an extreme case, conditions almost as bad were found in several instances. Two other plants were discovered treating acid water with sulphate of alumina only, rate controllers and loss of head gages were almost unknown, and the methods of regulating the amount of chemical applied were very crude. Few calibrated orifice boxes were found in use. Two gravity, rapid sand plants, treating waters high in organic matter and often turbid, had no coagulation basins, so that they required too frequent washing with corresponding reductions in bacterial efficiency as well as increased costs of operation. Another large plant, using the pressure type of filter, was treating a turbid water with very little time for coagulation. The effluent was frequently turbid, and at times contained aluminum hydrate.

One plant of the slow sand type had less than a foot of filtering sand, and had a clear-water well holding about a half hour's supply. As a result of this combination, the rate of filtration fluctuated exactly as the demand, and purification was practically *nil*.

At one rapid sand plant the clear-water basin was so small that it was necessary to wash with raw water. Another plant had no arrangement for filtering to waste, so that whenever it was necessary to get at the strainer system the dirty water in the bed was drained into the clear-water well.

On the matter of operation, conditions were found to be as bad if not worse. As has been said, the man in charge of a small water purification plant has usually little or no idea of the nature of the process. He operates the plant by "rule of thumb" methods in an endeavor to produce a good-looking water. Although efficient results depend so largely upon the use of the correct quantity of coagulant, the greatest ignorance was shown of this matter. At several plants the engineer stated that he put in a certain number of buckets of alum per day. He did not know how many pounds were used and made no attempt to add it in the same proportion at all times. A few engineers said that they increased the dose "some" when the water was turbid, but did not know how much. In only a few plants was any attempt made to regulate the dosage by the aid of alkalinity and turbidity tests. As a matter of fact, few of the men in charge could be depended upon to make the necessary alkalinity tests. At only two plants, treating less than twenty million gallons per day, were laboratories maintained, and at these plants the tests, both chemical and bacteriological, were made under the direction of non-resident chemists. The engineers who made the tests were unable to interpret them or apply them in the operation of the plants. At one modern municipal plant, absolutely no records were kept. The chief engineer could neither read nor write, and could see no use in records of any kind, not excepting pumpage records. The president of the board of water commissioners in charge of the plant stated that the only reason he could see for filtering water was to remove turbidity, notwithstanding the fact that the sewage of over a hundred thousand people was discharged in the

river, from which the supply was taken, about seventeen miles above the intake.

At one plant visited, it was found that through the laziness of the engineer the filters were not being washed enough, the deficiency of water due to clogging being made up by by-passing raw water. At another plant, the beds were washed too often, resulting in a low bacterial efficiency and a high cost of operation. Over ten per cent. of all water filtered was being used for wash water.

It is not believed that such cases are confined to New Jersey. Reports of investigations in Ohio, Pennsylvania, New York, and Illinois show very similar conditions. Much as they are to be deplored, the fact remains that they do exist, and that a discussion of possible remedies is in order.

The most feasible remedy for poor design is a statute requiring the submission of plans for proposed plants or changes in existing plants to the state board of health, or some other state authority, for approval before construction can legally be carried out. Such a regulation is in effect in a number of states at the present time. Coupled with the appointment of a properly qualified engineer to pass upon all plans, it will satisfactorily care for new works. State supervision for existing plants will if carried out do much to remedy the more serious imperfections of construction and operation. This supervision cannot, however, be thorough enough to furnish definite information for the efficient operation of the plant both from an economic and a sanitary standpoint. At best the plant can be visited only about once a month, and this visit is merely to see that a safe and potable water is being produced. From the viewpoint of the state this result is sufficient, but from that of the consumer and taxpayer there are other matters of great importance. He wishes to know, first, that the water is healthful, and then, that it is not possible to obtain the same or better results at a less cost by some change in the method of construction or operation of the plant. This latter is out of the field of the state inspector, for it generally requires much experimenting and testing to obtain the point of maximum efficiency.

The plan of having the engineer at the plant make daily tests under the general direction of a consultant at a distance is a step

in advance, but it is far from perfect. The engineer's results are open to question since he is often hurried and makes the tests without knowing the reason for the various steps. Also, since he has but infrequent consultations with the consulting engineer or chemist and is unable in most cases to explain any seeming discrepancy in his results, they do not prove to be of as much value as might be expected.

The writer has had in mind for some time a plan for remedying this situation, and it has recently again been brought to his attention by a similar plan which Prof. Earle B. Phelps has put into operation in connection with local health administration in several small Massachusetts towns. The plan is this: For several water companies or municipalities located not too far apart to combine forces, fit up a laboratory at some central point, and employ a competent bacteriologist and chemist to give his entire time to the scientific supervision of their water plants. By so doing, each plant would have the benefit of expert advice at a small cost. It would be possible for the chemist to visit each plant one or more days each week, and by so doing to become familiar with its operation. He could instruct the engineer in charge of the plant how to make the necessary daily chemical tests, such as alkalinity, turbidity, etc., and since he visited the plant so often, these results could be checked up and would be reliable. In case of emergency he would be able to look after the sanitary quality of the water and thus protect the consumer. He would be able to carry on experiments upon the proper amount of coagulants to be used, and time of coagulation. There is a chance for much study in the manner of washing the filters to bring about efficiency and economy. This is a point not considered much in small plants, but which has a considerable bearing on the cost of operation. It requires many visits to a plant to become familiar with its operation and to suggest changes which will increase its bacterial efficiency without increasing the cost. It is believed that the scheme outlined would in many cases save money for the water company or municipality, besides giving them and their consumers confidence that the quality of the water was being safeguarded.

DISCUSSION.

Mr. Paul Hansen (*by letter*).* Mr. Letton has presented a most striking picture of the manner in which the typical small water purification plant is neglected, and his suggestion for a remedy, namely, the establishment of laboratories at convenient points to serve two or more small purification plants, is a most excellent one. In practice, however, this is rather difficult of accomplishment, especially in the Middle West and Far West, where the distances between purification plants are rather great. Moreover, the difficulties, legal and otherwise, of securing co-operation in this way are almost insurmountable.

Mr. Letton has made a statement regarding the employment of a consulting engineer in connection with operation, and this, in my opinion, gives the clew to the practical and early solution of not only the management of the purification works but also the management of the entire water-works plant, including oversight of the finances and methods of accounting. In recent papers before the Western Society of Civil Engineers and the Illinois Society of Engineers and Surveyors, I advocated the employment on an annual basis of consulting engineers by small communities for the purpose of supervising water-works operation, including the operation of purification works. Such service could be obtained at very small expenditure, comparatively speaking, probably not exceeding six hundred dollars per annum for a small water-works plant in a town of not less than ten thousand population.

The advantages of this arrangement would be as follows:

(1) The public would receive better service.

(2) The cost of operation will be reduced, which means increased earnings.

(3) Future requirements will be anticipated, and thereby the water-works plant may be always kept in readiness to meet demands upon it. There are a number of instances in the state of Illinois where water supplies have failed and machinery has proved inadequate merely due to lack of foresight in anticipating what the future would bring forth.

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* Engineer, Illinois State Water Survey.

(4) The design of water works will be improved for the reason that the supervision by consulting engineers will give these engineers an opportunity to observe the manner in which their designs "work out" and enable them to appreciate the value of a great number of important details which in present practice are often overlooked. In short, the design and operation go hand in hand, and it is not possible for an engineer to master one without knowing a great deal about the other.

(5) A professional and personal advantage to engineers will result. The professional advantage relates, as already suggested, to the opportunity to acquire better knowledge of the problems before them, thereby rendering their services of greater value. It would also enable them to maintain a more efficient office organization, for with present methods it frequently becomes necessary for engineers to dispense with the services of some of their best men during periods when work is slack. The personal advantage relates to the increased income of consulting engineers, but this is a very minor consideration compared with the good to the general public that may be accomplished by thus increasing the scope of the consulting engineers' work.

PROF. GEORGE C. WHIPPLE (*by letter*).* The operation of the small water purification plant is indeed a difficult problem. The reason is that the attention required is the same in kind as that for a large plant, while the cost of proper supervision becomes disproportionately large when the quantity of water filtered is small. To keep this cost down it is customary to employ untrained operatives, and the result is that, as the author says, small plants are often badly conducted.

Where several small plants are near together, the plan of securing coöperation between them, each contributing to the support of a capable supervising engineer, would appear to be a promising one. Such a plan has been in operation in the water department of the city of New York for many years, although in this case the various plants are owned by the same authority, although scattered in location. The same general scheme is followed by some of the large water-works companies which control many plants that are still more widely scattered. Somewhat similar in character

* Professor Sanitary Engineering, Harvard University.

is the control exercised by state departments of health over the filter plants within their jurisdiction.

The difficulty with this plan is that the filters must operate all the time, while with any system of coöperation the supervisor's work is intermittent. The real dangers from filters may be said to be due to emergency troubles. Most filters work well most of the time. The best filters work well all of the time. The poor filters work badly on occasions, and the more frequent these occasions, the less safe is the filtered water. After all, it is the laborer in charge of the plant who needs to understand his job, for it is usually his hand that is at the throttle when things go wrong. At such time analytical work counts for nought and it is the horse-sense of the man on the spot that must be depended upon.

It must be recognized that the small plant must be operated at small cost, and in the writer's opinion the safety of such plants must lie in the education of the low-salaried attendant and in the selection of such sources of supply that irregularities in operation will produce less disastrous results than in the case of larger plants where a higher grade of supervision is possible. To secure the better appreciation by the operator of the general principles of sanitation, and a better understanding of the work which a particular filter is capable of doing, the supervision of the state authorities should be not so much punitive as pedagogical.

Mr. Letton also calls attention to the fact that small plants are apt to be "commercial" or "stock" plants rather than "specially designed plants." This also conduces to poor operation because the stock pattern may not be suited to the local conditions. All this is quite natural, but it is unfortunate. It is difficult to make small communities see that it pays for them to secure adequate advice in the beginning from persons not interested in selling goods. It almost goes without saying that a filter that is well adapted to local conditions can be depended upon to furnish regularly a better supply of water than one that is not, and the poorer the grade of operation, the more important is it that the filter be well adapted to its work.

When all things are considered, the surprising thing is not that the small plants are so badly operated, but that the protection

of the health of the people by the use of such badly run plants has been so good as statistics in many places have shown it to be.

Mr. Robert Spurr Weston (*by letter*).* To the author's examples of ignorance and carelessness of filter attendants and the unsuitableness and inadequacy of purification plants, the writer could add many others. Many a plant has been put in to satisfy a popular demand, or as a concession in a trade between corporation and city, hence the plant often is a name rather than a device producing safe and attractive water, and its operation is left, as Mr. Letton intimates, to the tender mercies of the untaught.

The writer's experience with the men at the ordinary small pumping station, say of less than one million gallons daily capacity, has been happier than Mr. Letton's and he has gained much by association with such men at plants represented in this Association. For example, one man at a station in a town of less than ten thousand has learned to make the ordinary analytical determinations, to operate a plant handling a water difficult to purify, and to inform himself by persistent reading of suggested books and of the reports of the Massachusetts State Board of Health of the fundamental principles and some of the fine points of water purification. Generally the writer has found these men teachable, — more than that, eager to learn.

But to make a filter attendant and analyst out of a water-works employee implies a teacher, and the writer is somewhat in doubt as to the best method to be employed. The possibilities are limited by the money available, which is less than the salary of a young analyst, — say, less than nine hundred dollars a year. Usually no small works can afford to pay over five hundred dollars a year for part-time services. Whether this amount paid by each of say three water works to a single filter superintendent, as suggested by Mr. Letton, or to an office employing several specialists, as suggested by Mr. Hansen, will yield better results, is still an open question. Personally, the writer feels that the judgment of an experienced consultant upon the observations of young engineers, chemists, and bacteriologists is more valuable than the service which could be rendered by one man in a central

* Consulting Sanitary Engineer, Boston, Mass.

laboratory for the same money. The fee for the consultant is very small for the service rendered, and is so because of the statistical information which because of his connection with the works is available for use in his practice. There is nothing to prevent the establishment of a central laboratory by the consultant. There is room for Mr. Letton's plan, and the writer hopes it will be tried out. The principal difficulty in the way of all plans of this kind is the location of the purification plants.

In larger places it is possible to make arrangements for the whole time of a young trained assistant, who is trained, sent out, and advised by some consulting office. This plan makes available the services of the consultant for a very low fee. The assistant would ordinarily hold such a position for a year or two and be supplanted by another trained in the consultant's office, and who probably had been engaged previously at some smaller plant on part-time service.

Mr. Letton has called attention to a glaring defect in one of the most important public-health services, and the writer hopes that his interesting paper will assist in remedying it.

The furnishing of the necessary professional service does not seem to the writer to be so difficult as to persuade works owners and managers that such service is necessary, and if so, to persuade them to pay for enough of it to safeguard the quality of their product. Fortunately, however, it is sometimes possible to effect economies in operation which compensate for part or all the cost of expert assistance.

Mr. Earle B. Phelps (*by letter*).* The writer fully agrees with Mr. Letton that the conditions described by him are in nowise extreme nor are they confined to the state of New Jersey. With our present development of the art of design and operation of water plants, and especially those plants which rely upon some form of chemical treatment, there exists an entirely inexcusable neglect of the equally important matter of daily operation. This is a matter of such common knowledge that it is unnecessary to dwell upon it further.

We turn with interest, therefore, to the remedies which are proposed. The writer has had practical experience with the practice

* Consulting Sanitary Expert, New York.

described by Mr. Letton of employing a consulting expert to have a general oversight of the plant and its operation. It was his custom for some time to receive daily reports from several such plants that were under his supervision, such reports including the simple chemical and bacteriological tests which the engineer in charge had been taught to make. Monthly visits to the plant and a monthly report to the water board were made. While such a system of supervision is far in advance of the ordinary procedure, it is without doubt subject to the difficulty which Mr. Letton has pointed out.

A particular weakness which may develop at any time and against which there seems to be no positive remedy is actual dishonesty on the part of the engineer who is supposed to make tests. The fact that the results remain fairly uniform day after day may suggest the idea that the record is just as valuable if the tests were not actually made. The consulting engineer may be caused rather serious embarrassment because of his reliance upon the accuracy of these reports.

The writer is especially interested in the suggestion of a more close and more scientific supervision of these plants through a coöperative working agreement. The feasibility of such a plan has been fully demonstrated in some coöperative work along the line of general board of health administration to which Mr. Letton has referred. A small group of towns in the vicinity of Boston have engaged the services of a staff of experts in the various lines of board of health administration and during the past year have obtained the services of trained workers in these various lines at a cost which is within their means, although the cost to any single town would have been prohibitive. The same principle holds in the case of small water plants. A small portion of the services of the expert will suffice at any one plant so that it is quite feasible to divide his time among a number of plants within easy traveling distance. The chief difficulty in such a plan as this lies in the distribution of expenses and of the expert's time. There is also opportunity for confusion of authority and, in the case of our board of health work at least, a tendency on the part of the various parties interested to expect rather more than their just share of the service.

The matter of division of expenses has been regulated by a definite agreement and contract between the writer and the individual towns in such a way that, while the movement as a whole is coöperative, the towns deal with only one man upon a strict contract basis. No town, therefore, has any right to question whether it is paying too much of the general cost of the work, although even now such a question does arise.

The distribution of services is a somewhat more difficult matter, especially in board of health work where the only limit to the amount of work that can be done is fixed by the available time and men. We have handled this matter somewhat arbitrarily, relying wholly upon a systematic time card, on the basis of which we are able at the end of the year to show each town what proportion of the total work of the staff has been devoted to their individual needs. In this manner, while we have not entirely escaped criticism, we have been able to apportion the services rendered to the incomes received from the various communities, with reasonable fairness.

It will be exceedingly difficult for any group of towns to mutually agree upon a proper distribution of expenses in an undertaking of this kind. The only hope of successful application to the water-works problem lies in an individual agreement between the expert and the various authorities, or, perhaps better still, in the state or other central authority initiating this work nominating or approving the appointee and arbitrarily apportioning the cost.

PROCEEDINGS.

HOTEL BRUNSWICK,
BOSTON, MASS., November 12, 1913.

Vice-President William F. Sullivan in the chair.

The following members and guests were present:

HONORARY MEMBER.

William T. Sedgwick. — 1.

MEMBERS.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, F. H. Carter, J. C. Chase, R. D. Chase, W. F. Codd, F. L. Cole, A. O. Doane, L. R. Dunn, E. D. Eldredge, G. F. Evans, F. L. Fuller, Patrick Gear, F. J. Gifford, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, J. O. Hall, A. R. Hathaway, T. G. Hazard, Jr., D. A. Heffernan, J. L. Howard, A. C. Howes, J. L. Hyde, Willard Kent, Patrick Kieran, G. A. King, F. A. McInnes, J. A. McMurry, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, F. L. Northrop, T. A. Peirce, H. E. Perry, Dwight Porter, L. C. Robinson, H. F. Salmonde, P. R. Sanders, C. M. Saville, A. L. Sawyer, G. A. Stacy, G. T. Staples, E. L. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. J. Turnbull, F. E. Tupper, W. H. Vaughn, F. B. Wilkins, F. I. Winslow, G. E. Winslow. — 62.

ASSOCIATES.

Ashton Valve Company, by H. H. Ashton; Builders Iron Foundry, by F. N. Connet and A. B. Coulters; Chapman Valve Manufacturing Company, by J. T. Mulgrew; Darling Pump and Manufacturing Company, by H. M. Pickersgill; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by R. D. Wertz; Pittsburgh Meter Company, by J. W. Turner; Platt Iron Works Company, by J. H. Hayes; The Pratt & Cady Company, by Charles E. Pratt; Rensselaer Manufacturing Valve Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Standard Cast Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company;

by E. K. Otis; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison and E. P. Howard. — 25.

GUESTS.

Nathan C. Rockwood, assistant editor *Engineering News*, Fred W. Schultz, *Engineering News*, and D. A. Decrow, New York, N. Y.; C. J. Callahan, Lewiston, Me.; F. N. Strickland, assistant superintendent water works, Westfield, Mass.; Francis Sears, Plymouth, Mass.; Harry Greenalgh, Fall River, Mass.; Prof. L. J. Henderson, assistant professor, Harvard University, Cambridge, Mass.; D. J. Higgins, superintendent water works, Waltham, Mass.; and R. Forrest, Randolph, Mass. — 10.

The Secretary presented the following applications for membership, properly endorsed and recommended by the Executive Committee: Joseph A. Rourke, Boston, Mass., mechanical and civil engineer; Joseph Walton Ellms, Cincinnati, Ohio, superintendent Cincinnati Filter Plant; Moses J. Look, Brown Station, N. Y., with New York Water Works as general superintendent for contractor; Arthur E. Walradt, New Rochelle, N. Y., lawyer representing sewer and water-works corporations; H. A. Von Schon, Detroit, Mich., consulting hydraulic engineer.

On motion of Mr. Albert L. Sawyer, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared duty elected members of the Association.

The Secretary read the following:

"The American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers, extend to the officers and members of the New England Water Works Association a most cordial invitation to attend and to participate in the proceedings of the International Engineering Congress to be held in connection with the Panama-Pacific International Exposition, September 20 to 25, in the year 1915, in San Francisco, California."

On motion of Mr. Lewis M. Bancroft, it was voted that the application be received and placed on file.

MR. GEORGE A. STACY. It seems, under the circumstances, Mr. President, that it is desirable, or will be desirable, to increase

the number of the committee on water purification and statistics. I therefore move that the President of the Association be authorized to make such addition to the committee as seems to him desirable. (Adopted.)

The first paper of the afternoon was entitled "Cleaning Water Mains in Hartford, Conn.," by Caleb Mills Saville, chief engineer, Board of Water Commissioners, Hartford, Conn. The paper was discussed by Mr. Frank L. Fuller, Mr. Burt B. Hodgman, chief engineer of the National Water Main Cleaning Company, Mr. Edwin C. Brooks, Mr. Frederic I. Winslow, and Mr. William F. Codd.

"Water and Life" was the subject of a paper by Lawrence J. Henderson, M.D., professor of biological chemistry, Harvard University. Professor Sedgwick and Professor Porter followed with brief remarks.

The subject for topical discussion was "Advisability of Securing Legislation for Making Water Bills a Lien upon the Property Supplied." The following-named gentlemen participated in the discussion: Robert J. Thomas, A. R. Hathaway, George A. King, Arthur F. Ballou, Lewis M. Bancroft, Frank L. Fuller, John O. Hall, Frank A. McInnes, Alfred L. Sawyer, and Percy R. Sanders. At the close of the discussion it was voted that the Executive Committee be directed to appoint a committee of five, with John O. Hall, of Quincy, as chairman, to take all necessary and desirable means to secure the passage of a statute in Massachusetts making water bills a lien on real estate.*

Adjourned.

HOTEL BRUNSWICK,
BOSTON, MASS., December 10, 1913.

J. Waldo Smith, President, in the chair.

The following-named members and guests were present:

HONORARY MEMBERS.

Frederic P. Stearns and William T. Sedgwick. — 2.

* For the appointment of the committee see page 553

Members.

N. W. Akimoff, S. A. Agnew, M. N. Baker, L. M. Bancroft, R. D. Barnes, H. K. Barrows, G. W. Batchelder, C. R. Bettes, A. E. Blackmer, J. W. Blackmer, George Bowers, G. A. Carpenter, E. J. Chadbourne, R. D. Chase, J. H. Child, R. C. P. Coggeshall, F. L. Cole, M. W. Davenport, J. C. DeMello, Jr., John Doyle, H. P. Eddy, E. D. Eldredge, G. F. Evans, F. F. Forbes, A. S. Glover, J. M. Goodell, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, E. A. W. Hammatt, T. G. Hazard, Jr., Allen Hazen, D. A. Heffernan, A. C. Howes, F. J. Hoxie, W. S. Johnson, Willard Kent, G. A. King, F. H. Luce, A. E. Martin, John Mayo, J. H. Mendell, F. E. Merrill, H. A. Miller, J. J. Moore, William Naylor, A. S. Negus, F. L. Northrop, T. A. Peirce, Dwight Porter, H. E. Royce, P. R. Sanders, H. W. Sanderson, A. L. Sawyer, W. P. Schwabe, J. Waldo Smith, G. A. Stacy, W. F. Sullivan, R. J. Thomas, E. J. Titcomb, D. N. Tower, G. W. Travis, C. H. Tuttle, W. J. Turnbull, W. H. Vaughn, F. P. Washburn, F. B. Wilkins, F. I. Winslow, G. E. Winslow, H. B. Wood, I. S. Wood. — 73.

Associates.

Ashton Valve Company, by H. H. Ashton; Builders Iron Foundry, by A B. Coulters; Chapman Valve Manufacturing Company, by J. F. Mulgrew and H. E. Steer; Hersey Manufacturing Company, by Albert S. Glover; Kennedy Valve Manufacturing Company, by M. J. Brosnan; Lead Lined Iron Pipe Company, by T. W. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; National Meter Company, by J. G. Lufkin and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Platt Iron Works Company, by F. H. Hayes; Pratt & Cady Company, by C. E. Pratt; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. L. Northrop; Standard Cast Iron Pipe and Foundry Company, by William F. Woodburn; Thomson Meter Company, by S. D. Higley; Union Water Meter Company, by E. P. King and F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 24.

Guests.

Fred Cole, Frank E. Davis, William Grant, and E. P. Howard, Boston, Mass.; James Pintech, East Greenwich, R. I.; George W. Bowers, Lowell, Mass.; Albion Davis, Waltham, Mass.; Hiram C. Jenks, Pawtucket, R. I.; C. C. Covert, Albany, N. Y. — 9.

The President. It is with great regret and sadness that I have to announce that during the past week our old friend and member, Mr. Horace G. Holden, has passed on.

Out of respect to his memory, and in consideration of the fact that he was one of the charter members of this Association, I will ask you all to stand and observe a moment's silence.

The President's suggestion was followed, and all stood in silence.

Mr. R. C. P. Coggeshall. Mr. President, early in the year of 1882, the month of February, I had occasion to go to the city of Lowell to look up some matters in connection with water-works experience. At that time I first met Horace G. Holden. At the same time Mr. Frank E. Hall was there, and a delightful acquaintance commenced on that day. Later in the day we all three went to Lawrence, and there met Mr. Henry W. Rogers, who was then the superintendent. We four men at that time discussed the possibility of an association, — not as large as this, for we never dreamed it, but an association that would meet in Boston occasionally, once a month or so during the winter, and have a dinner and a talk. Each one of us four, aided by Mr. Albert S. Glover, who afterwards came in and did a tremendous amount of work, were charter members of this Association, which held its first meeting June 21, 1882. Of the seventeen charter members of the Association, there are four survivors, — Mr. Hall, Mr. Glover, and myself, and Mr. Richard W. Bagnell — who at the advanced age of ninety-two is in good health and living in Plymouth, Mass.

We all remember Horace Holden for his cheery face and kindly smile. He was always the same man in all the years that I knew him. We shall miss him much, and peace be to his memory.

Mr. President, at this time I would suggest that a committee be appointed to prepare an appreciation of Mr. Holden for the pages of our Journal.

Mr. George A. Stacy. Mr. President, I move that the committee shall consist of the four surviving charter members of the Association.

The President put the motion, and declared it unanimously adopted and the committee appointed.

The Secretary presented applications for membership, duly recommended and endorsed, from Hiram C. Jenks, Pawtucket,

R. I., engaged in making surveys for underground sources of water supply; Sheldon S. Yates, Cambridge, Mass., instructor in civil engineering, Harvard Graduate School of Engineers; F. A. Dallyn, Toronto, Ont., engineer in charge of experimental station in 1910, Provincial Board of Health, Ontario, 1913, provincial sanitary engineer, 1913; Scotland G. Highland, Clarksburg, W. Va., secretary and general superintendent of the water works and sewerage systems of Clarksburg, W. Va.; C. R. Elder, Amherst, Mass., for ten years general superintendent and constructor of water-works plants and railroad water supplies, for past eight years superintendent of the Amherst Water Company.

On motion, the Secretary was directed to cast one ballot in favor of the admission of the applicants, and he having done so they were declared duly elected members of the Association.

The first paper of the afternoon was by X. H. Goodnough, chief engineer of the Massachusetts State Board of Health, on "Rainfall." The paper was illustrated by diagrams showing variations in rainfall for different periods. Before reading his paper, Mr. Goodnough said:

This paper was begun with the idea of collecting all of the rainfall records available in New England, also the record of flow of streams. It was a scheme that I began with Mr. Safford, and we hope some day to complete it. Much of the work of collecting records and analyzing them has been done by Mr. R. M. Whittet, of the State Board of Health, and the diagrams by Mr. Crowhurst of the same office.

Mr. Goodnough's paper was discussed by Mr. Winslow, Mr. Allen Hazen, and Mr. Fitzgerald.

Mr. N. W. Akimoff, Philadelphia, Pa., presented a paper entitled "On Flow in Bends." This paper was also illustrated.

The third paper on the program for the afternoon was entitled "Small Water Purification Plants, a Plea for Their More Efficient Operation," by H. P. Letton, sanitary engineer, Washington, D. C. Mr. Letton was unable to be present, but sent as his representative, Mr. Grant, of Nebraska, who read the paper. The paper was discussed by Mr. Earle B. Phelps and by Mr. G. C. Whipple, in writing.

It was voted that the topical discussion on "A Comparison of

Methods Used to Locate Hidden Leaks in Underground Pipes, with Special Reference to Pipe whose Actual Location is Unknown" be put over till the February meeting.

Mr. John O. Hall. Mr. President, I would like to make a request at this time of the superintendents who are present now, asking them to assist the committee to which was referred the proposed legislation for making the water bills liens upon real estate. Will they please send to the headquarters of the Association, addressed to Mr. John O. Hall, the total amount of their water revenue, and also the amount uncollected by reason of failure to obtain it from the tenant of the estate; not only the amount lost, but the amount that has delayed collection and increased expense in court. The total of that amount will be an important factor in securing the legislation which we desire, and I trust that all superintendents of water works present will get that information in at as early a date as possible. This request will also be made at the January meeting, so that our case may be in shape when we present it to the legislature.

Mr. Coggeshall. Mr. President, I believe that important information would be better collected for Mr. Hall by having a circular prepared and sent out by the Association, so that each question can be answered right on the blank and returned to him. I think in that way he will get better results than he would by trusting to the memory of the gentlemen present.

Mr. Hall. Mr. President, my idea in making that announcement now was to save work for the clerk, and also expense to the Association. We shall probably have to send that blank, but I thought that we could save expense by first ascertaining to whom we must send in order to get the information.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at the rooms of the Association, Tremont Temple, Boston, Mass., Wednesday, November 12, 1913, at 11.30 A.M.

Present, Vice-President William F. Sullivan and members Samuel A. Agnew, Lewis M. Bancroft, Richard K. Hale, George A. King, and Willard Kent.

The present Committee to look after and keep track of legislation and other matters pertaining to the Conservation, Development, and Utilization of the Natural Resources of the Country, namely, Messrs. M. N. Baker, William T. Sedgwick, Leonard Metcalf, Allen Hazen, and George A. Soper, were, by unanimous vote, authorized to represent the New England Water Works Association as delegates to the Fifth National Conservation Congress to be held in Washington, D. C., November 18, 19, and 20, 1913.

Invitations from New York and Atlantic City to hold our next annual convention in those cities were referred to the Executive Committee of the Association for 1914.

The Secretary was duly authorized to procure a new typewriting machine.

WILLARD KENT, *Secretary.*

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at headquarters, Tremont Temple, Boston, Mass., December 10, 1913.

Present, Vice-President William F. Sullivan, and members Lewis M. Bancroft, Samuel A. Agnew, Richard K. Hale, George A. King, and Willard Kent.

Voted, That John O. Hall, Frank A. McInnes, Robert J. Thomas, George A. King, and A. R. Hathaway be, and hereby are appointed, a committee to secure legislation necessary to make water bills a lien on property.

Five applications for membership were received, viz.:

For members: Scotland G. Highland, secretary and general superintendent Clarksburg Water Works and Sewerage Board, Clarksburg, W. Va.; F. A. Dallyn, provincial sanitary engineer, 137 Geoffrey Street, Toronto, Ontario; Sheldon S. Yates, instructor in civil engineering, Harvard Graduate School of Engineering, Pierce Hall, Cambridge, Mass.; Hiram C. Jenks, surveyor for subterranean sources of water supply, 8 Manchester Street, Pawtucket, R. I.; C. R. Elder, superintendent Amherst Water Company, Amherst, Mass.;

and the applicants were by unanimous vote recommended for admission to membership.

Voted, That William F. Sullivan, Richard K. Hale, and Willard Kent be, and hereby are constituted, a committee to procure a design for certificate of membership.

WILLARD KENT, *Secretary*.

OBITUARY.

Horace Gage Holden, previous to his decease one of the five living charter members of this Association, died at his home in Nashua, N. H., on December 7, 1913. He was born at Concord, Mass., on October 29, 1838. He was the son of Frederick Artemus and Hannah (Page) Holden. On May 24, 1862, he married Ruthanna, daughter of David and Mary (Sawyer) Butterfield, of Tyngsboro, Mass., who survives him. Three children were born of this marriage: Frank, who died in 1872; Frederick Artemus Holden, now living in Nashua, N. H., and Ida, now the wife of Col. Charles S. Proctor, of Lowell.

Horace G. Holden attended the public schools of Lowell, and after finishing with the high school of that city entered the office of the distinguished engineer James B. Francis, Esq., at Lowell. Here from 1858 to 1863 he was engaged at various duties connected with hydraulic engineering, prominent among which was the gaging of flows of water allotted to the various corporations. In October, 1863, he located at the easterly portal of the Hoosac Tunnel, and assumed the position as superintendent of construction of the easterly section of that work. Here he remained continuously until January, 1870. We are not informed in regard to his activities in the years which follow 1870 until May, 1879, at which time he became superintendent of the Lowell Water Works. Here he remained for eight years.

During the year 1887 he entered the employ of Turner, Clark & Rawson, of Boston, who were engaged in financing various waterworks enterprises in the West. Mr. Holden became their active superintendent, and was located at Minneapolis, Minn., for a few months. October, 1887, he was offered the superintendency of the Pennichuck Water Company, of Nashua, N. H., which he immediately accepted. He held this position until October, 1906,

when he resigned. From that time until the date of his death he did not resume any active employment.

The name of Horace G. Holden will always remain important in the annals of this Association. He was a lively member of that little group who worked so assiduously to effect the successful organization of this society in 1882. He served this Association upon its Finance Committee in 1882–83; was a member of the Executive Committee, 1895 to 1897 and 1902 to 1904; was Vice-President, 1883–85 and 1889–90, and was President, 1891–92. The detailed story of his work in this Association has been told heretofore and does not now require repetition. Suffice it to say that he remained an active and loyal member to the end of his days.

A member of his family recently remarked that his strong characteristics could be summed up in two words, "homespun" and "generous." Homespun he certainly was. The old-fashioned New England mode of living appealed to him strongly, and he had no sympathy with the artificialities of modern society. Never was a man more generous, and it gave him exceeding joy to share by word and deed with those he loved. He was blessed with the best of health until the decline which appeared a few months ago. He had a most cheery spirit which drew friends to him wherever he went. The value of such a life is no more to be measured than the sunshine, for like the sunshine it brought joy to those with whom he came in contact, and its wholesome influence will endure long beyond the sunset.

Peace be to his memory.

R. C. P. Coggeshall,
F. E. Hall,
R. W. Bagnell,
Albert S. Glover,
Committee.